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Managing Animal Wastes

Guidelines for Decisionmaking

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MANAGING ANIMAL WASTES: GUIDELINES FOR DECISIONMAKING, by L. A. Christensen, J. R. Trierweiler, T. J. Ulrich, and M. W. Erickson, Natural Resource Economics Division, Economic Research Service, U.S. Department of Agriculture. ERS-671.

ABSTRACT

Economic concepts can help farmers evaluate changes needed in their waste management systems to meet the challenges of environmental regulations and of rising energy and fertilizer costs. The concepts of diminishing returns, fixed and variable costs, opportunity costs, budgeting, and amortization are applied to several typical livestock production situations--dairy herds in the Lake States, Southwest, and Southeast; a Corn Belt hog operation and a large confinement hog operation; and a Corn Belt cattle feeder operation. Although more intensive manure management generally preserves more nutrients, additional direct costs of meeting environmental goals or expanding operations exceed nutrient recovery benefits.

Keywords: Livestock waste management, decisionmaking guides, opportunity costs, amortization, budgeting, environmental constraints, manure utilization.

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PREFACE

In 1979, the U.S. Department of Agriculture's Science and Education Administration published the report, Animal Waste Utilization on Cropland and Pastureland, to address the issue of agronomic application rates of animal waste and the potential of water pollution resulting from nutrient runoff, primarily nitrogen and phosphorus. The study also included several other variables: application timing, climate, soil type and slope, cropping system, form of the manure (solid, liquid, or slurry), and problems resulting from soil salinity. It only briefly discussed economic issues.

Our report presents a broader discussion of economic issues that planners should consider when analyzing livestock waste management systems. Support for this report was provided by the U.S. Environmental Protection Agency under Amendment No. 1 to EPA-IAG-D6-0029. The project officer was Lynn Shuyler of the Robert S. Kerr Environmental Research Laboratory in Ada, Okla.

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SUMMARY

Increased environmental regulations, rising energy costs, and rising fertilizer costs are forcing livestock farmers to rethink their attitudes toward livestock waste management. The manure formerly considered a waste product to be disposed of can also be treated as a resource to be managed. Economic concepts provide tools for making better decisions regarding available waste management systems.

This management guide demonstrates the relevance of economic concepts and procedures to typical livestock producing situations. It highlights the principles of diminishing returns, fixed and variable costs, budgeting, and amortization. Six examples from diverse types of livestock operations in disparate geographical areas illustrate the selection process. One should remember that the findings for each type of waste management system demonstrate relative economic relationships; the guidebook does not offer specific recommendations. Users must tailor their evaluations to their own situations and cost data.

Farmers faced with a decision to expand, modernize, or meet environmental goals will go through several steps in the process. They must determine the added costs and benefits of each alternative. They must then determine whether each alternative will meet the objectives. They can organize cost data into a partial budget format to compare alternatives based on total costs, capital and labor requirements, environmental impacts, and nutrient recovery. Finally, they can select a waste management alternative based on minimum cost and resource constraints.

In the first example, a Lake States dairy farmer has a 54-cow herd with a stanchion barn and must alter operations because of an environmental regulation discouraging manure application to frozen ground. The farmer evaluates two alternatives which provide 6-months storage capability and compares them with the existing system of daily field spreading. The first option uses a piston pump with transfer for storage, and the second option uses a stacker elevator. The alternatives require an additional investment between $5,500 and $8,400. There is a slight laborsaving reduction cost with each option over the existing system and a slight increase in the returns from manure as plant nutrients. However, the net change in annual costs is between $200 and $800 for each system. Thus, meeting the environmental regulations would increase operator costs; this increase illustrates the problem farmers face in meeting environmental regulations. These costs are borne directly, but could be shared through development of Federal, State, or local cost-sharing arrangements.

The Southwestern dairy herd example is a 280-cow herd on a drylot using a milking parlor system. The farmer wants to evaluate the costs and returns associated with adding a settling channel and collection pond to current facilities. The existing system allows animal waste to accumulate on the lot and then be loaded into a solid spreader for field application. An offset to the costs is associated with adding the channel and collection ponds because some solids can be recovered and used on cropland. Using a partial budget analysis, the farmer concludes the investment would be $2,700 and annual costs would be $308. There were additional returns from manure as plant nutrients, but not enough to offset the increased costs. Thus, there is an annual net change of $90 in adopting the practice.

A Southeastern dairy farmer with a 75-cow milking herd is remodeling existing facilities and wants to compare the respective costs of solid and liquid handling systems. The options are: a solid-waste handling system with daily scraping, hauling, and spreading; a liquid-waste handling system with daily scraping, holding tank storage, tank hauling, and injection; and a liquid-waste handling system with a twice-daily automatic flush system, lagoon storage, and cropland irrigation. The farmer determines the additional investment requirements, develops cost estimates, and estimates manure production and the nutrient value available for crop use. The additional investment ranges from $4,400 to $13,800; annual operating costs increase between $1,000 and $1,650. But, when the value of nutrients in the manure is incorporated, the net change in annual costs for the three options ranges from a minus $393 to a plus $2,622. If the only constraint is to minimize investment cost and labor, the solid-waste handling system is the best choice. However, as the third option requires less labor, the dairy farmer must decide whether the labor saving is worth the added investment.

The Corn Belt hog operation analyzed markets 650 head of slaughter hogs per year. The farmer faces a regulation that prohibits manure application on frozen ground and a recommendation that 6-months manure storage be available with the plowdown of manure as soon as possible after application. Two options provide for 6-months storage. In the first, the lots are scraped twice a year, and the manure is spread and incorporated; in the second, a ditch embankment around the drylots, a solid settling basin, and a grass infiltration area are added. The two options require between $1,500 and $2,100 additional investment, and they have a slightly higher annual operating cost than the existing system. To offset these higher costs, the value of nutrients in the manure recovered increases

slightly. However, the net change in annual operating costs for meeting the environmental guidelines is between $150 and $300.

Waste management alternatives are evaluated for a totally confined, 1,600-head hog production system when environmental regulations prohibit winter spreading of manure on frozen land. The farmer has the following options: (1) slotted floors with storage pits, above-ground storage tanks, and tank wagon injection to fields; (2) slotted floors with storage pits, below-ground storage tanks, with tank wagon application and plowdown; (3) slotted floors with storage pits, lagoon storage, and tank wagon injection to the fields; and (4) slotted floors with storage pits, lagoon storage, and irrigation to the fields. Investment options range from $13,700 to $20,500. Annual operating costs are nearly the same for options 1, 2, and 3, but are significantly lower for option 4. Total annual costs range from a high of $5,000 for option 1 to a low of $3,500 for option 2. However, the significantly larger return from nutrients recovered with options 1 and 2 substantially reduces their net increase in annual costs. Consequently, the highest net annual increase is for option 4--followed by options 3, 1, and 2. The irrigation cost of option 4 might be reduced if some equipment costs are charged to cropping operations. Thus, the management of manure as a resource contributes an offsetting benefit, but not sufficient to meet all additional costs.

In the final example, a Corn Belt feedlot operator evaluates expansion of current lot capacity from 150 to 500 head. To obtain permission from the State's stream pollution control board, the farmer must develop waste treatment and runoff control facilities either: (1) by paving the existing lot, constructing a shelter, settling basins, and a holding pond, or (2) by expanding the dirt lot with fences and constructing a settling basin and holding pond. Annual ownership costs of option 1 are $7,200, compared with $525 for option 2. Both options meet environmental goals. However, in developing annual ownership cost figures for option 2, the farmer ignored the opportunity cost of the land which must be converted to feedlot with a drylot expansion; to be comparable, each option should incorporate an opportunity cost of approximately $1,700 an acre for the land.

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INTRODUCTION

U.S. livestock producers face serious economic pressures caused by increasing production costs and increased variability in prices for finished livestock products. New environmental regulations have made the management of waste products from livestock production yet another critical problem that livestock farmers must address. Historically, manure management received little attention. Wastes were often considered a nuisance to be disposed of in the quickest, easiest, and least costly way--following the adage, "out of sight, out of mind."

Our manual presents basic procedures that livestock producers can use to evaluate the economic feasibility of available waste management technologies. It suggests a decisionmaking process, identifies basic economic principles and tools, and applies them to alternative management practices. Although several potential uses for manure, such as methane gas, recycling as animal feed, and protein production, are being investigated, our report addresses only the fertilizer potential. Similar procedures could be used for evaluating other uses.

Three factors are causing livestock managers to rethink their attitudes toward livestock waste management--increased environmental regulations, rising energy costs, and increasing fertilizer costs. Although these factors evolved independently, their solutions are interrelated. Steps taken to meet environmental goals and regulations can also lead to increased recovery of nutrients from animal waste materials. This complementarity needs to be considered in planning efforts where environmental guidelines or regulations exist. Although the cost of production may increase due to environmental regulations, farmers can realize some offsetting benefits to these increased costs.

The basic legislation influencing livestock waste management is Public Law 92-500 as amended by Public Law 95-217 (the Clean Water Act). This legislation reaffirms the objective of restoring

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and maintaining the quality of the Nation's water. Section 208 of Public Law 92-500 addresses nonpoint sources of water pollution, including livestock and crop production. Farmers and environmental planners trying to meet environmental laws and regulations must consider economic factors in their evaluation of waste management systems and the use of livestock manure for crop production. Our manual provides some guidelines for economic analysis.

Section 208 planners are particularly concerned about management practices for handling livestock and poultry manure. Livestock and poultry manure contain a number of plant nutrients that may become pollutants when mismanaged. Poorly timed and improper applications of these wastes to land are a potential source of water pollution. Nutrient concentration in surface runoff may increase, thus transporting oxygen-demanding materials or pathogenic agents into waterways. Subsurface flows can also contribute to stream degradation.

Intensified production methods have increased water pollution potential from livestock and poultry waste over the years. Large feedlots and dairies have already implemented procedures for controlling water pollution traceable to specific sources. State and local governments are developing plans and guidelines for controlling the water pollution from agriculture and forestry operations not already included under the point source regulations.

Livestock and poultry producers, who will be faced with new investments in manure collection and storage facilities, will obviously be interested in the potential of manure as a partial substitute for commercial fertilizer. They will also be interested in current manure handling technologies, costs of applying these technologies, and economic procedures for evaluating the various technologies on their own farms.

Thus, a major question livestock and poultry producers must now address is: Can manure, which has been treated as a waste product, be economically managed as a productive resource? Producers on many farms will find land application of manure to be a viable economic strategy. Other operators will find that the costs will exceed the benefits. Their best alternative may be to dispose of the waste at least possible cost while maintaining the integrity of the environment.

FRAMEWORK FOR DECISIONMAKING

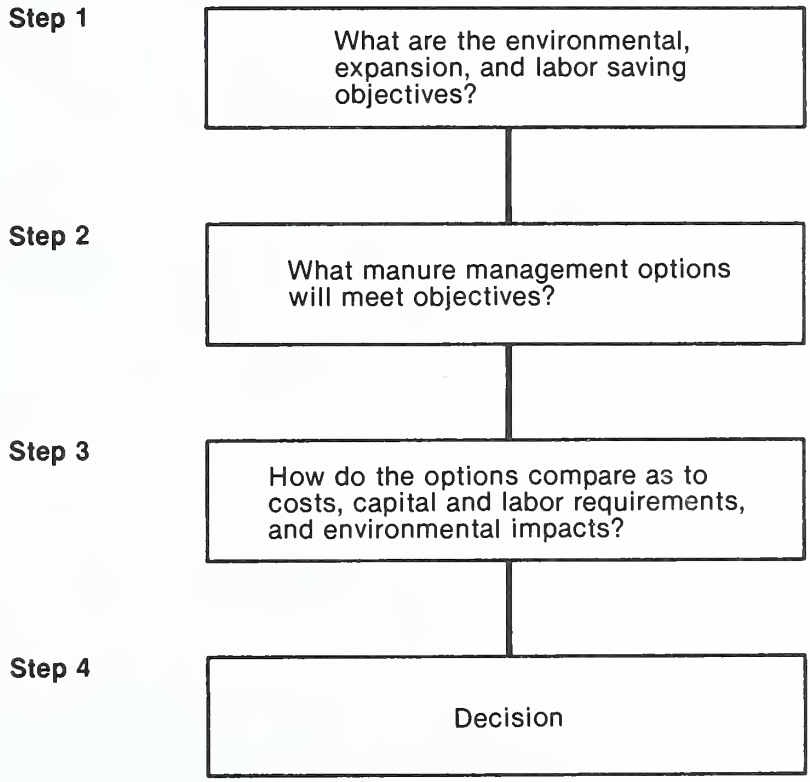
Livestock producers are faced with one or more decisions whenever changes are required in their operations. A change in the waste management system may be necessary to meet environmental objectives or because producers want to expand, modernize, reduce labor or energy use, or otherwise change their

operations. The decisionmaking process may be similar to that illustrated in the figure. Environmental planners may also follow this evaluation process in developing recommendations. Alternatives for waste management can be identified and evaluated for both economic and environmental impacts. After tradeoffs are assessed, the best management system for the situation can be selected.

The decisionmaking process requires technical information available from diverse sources. Sources of information include county extension agents, local universities, equipment dealers, agricultural engineers, the Soil Conservation Service (SCS), and other Federal agencies with agricultural waste management expertise.

After farmers collect information on the most pertinent technical solutions, they still must decide which is the most appropriate and economical for their operations. Many factors

Steps In Evaluating Manure Management Options


Step 1
What are the environmental, expansion, and labor saving objectives?
Step 2
What manure management options will meet objectives?
Step 3
How do the options compare as to costs, capital and labor requirements, and environmental impacts?
Step 4
Decision

affect the decision to undertake proposed changes, including the length of an individual farmer's planning horizon, availability and costs of capital, and type of farming operation. The main factor that we assume influences the selection process is the net cost of each proposed system--that is, the total cost less the value of nutrients realized from the system amortized over the expected lifetime of the system. An important factor in this decisionmaking process is the extent to which manure can be used as a productive resource rather than treated as a waste product.

Many farmers will find land application of manure an economically viable strategy which provides a positive return to resources invested. Other operators will find that the additional investment, labor, or management needed to use animal waste as a productive resource will be less than the benefits realized. Their best alternative may be to dispose of the waste at the lowest possible cost while maintaining the integrity of the environment.

ECONOMIC CONCEPTS AND PROCEDURES

Livestock and crop production involves a continual series of farm-level decisions. One of the most important decisions is how to organize the available resources to maximize profits. In crop agriculture, resource inputs typically include land, seed, fertilizer, water, labor, and capital. Outputs include products such as corn, wheat, or hay. In livestock production, resource inputs include labor, grain, roughages, proteins, minerals, and equipment, including those for manure handling and management. Outputs include milk, meat, and poultry products.

A farmer's decisionmaking process in organizing inputs for production may be very structured, or it may be little more than an intuitive judgment. Regardless of the method, the decisionmaker can usefully employ economic concepts such as the principle of diminishing returns, the principle of fixed and variable costs, and the concept of opportunity costs. These concepts can be incorporated into relatively simple tools for economic analysis, such as a complete budget or a partial budget.

Principle of Diminishing Returns

The concept of diminishing returns represents a physical relationship and simply states that after some point each additional unit of input adds less to total output than the previous unit. In more formal terms, the law of diminishing marginal physical returns states that as the amount of a variable input is increased, with the amount of other fixed inputs held constant, a point is reached beyond which marginal product declines. The basic physical relationships between inputs and outputs stated in this law of diminishing returns is extremely useful in economic analysis. When respective prices are

assigned to the output (for example, corn) and to the input (for example, nitrogen), the outputs and inputs are expressed in the same term--namely, dollars. Expressing the relationship in this manner aids in deciding how much fertilizer to apply. One has only to find the nitrogen application rate where profit is greatest--that is, where the total revenue exceeds the total cost by the largest amount. This application rate occurs when the value of the additional yield is equal to the additional cost of producing that yield. A greater application rate of nitrogen will cost more than it returns.

The data in table 1 illustrates the principle of diminishing returns. Maximum physical production is 146 bushels per acre, where 200 pounds of nitrogen are applied. However, with the respective prices of corn and nitrogen at $2.20 per bushel and at 16 cents per pound, only 160 pounds would be applied to obtain a 144-bushel yield. Additional nitrogen applications would cost more than the value of the additional yield.

A few generalizations are appropriate, relative to diminishing returns. First, excessive input of a single resource, such as fertilizer, pesticides, water, labor, or seed, will result in reduced profit and output. Second, not only are the revenues

Table 1--Hypothetical relationship between nitrogen application rates and corn yield 1/

Bushels per acre	Value of total yield	Value of additional yield	Total pounds and cost of nitrogen		Cost of additional nitrogen	Change in net revenue
	Dollars		Pounds		Dollars	
81	178.20	--	--	--	--	--
105	231.00	52.80	40	6.40	6.40	+46.40
124	272.80	41.80	80	12.80	6.40	+35.40
137	301.40	28.60	120	19.20	6.40	+22.20
144 2/	316.80	15.40	160	25.60	6.40	+9.00
146 3/	321.20	4.40	200	32.00	6.40	-2.00
143	314.60	-6.60	240	38.40	6.40	-13.00

-- = Not applicable.
1/ Corn priced at $2.20/bushel; nitrogen at $0.16/pound.
2/ Profit-maximizing yield.
3/ Maximum physical yield.

lost and the costs increased, but in the case of inputs such as fertilizer and pesticides, the potential for environmental degradation increases with heavier application rates. Excessive and poorly timed application of fertilizer may mean not only lost profit to the farm operation but also a cost to society in the form of diminished water quality.

Fixed and Variable Costs

Two other important concepts in the evaluation of animal waste management systems are fixed and variable costs. Definitions of fixed and variable costs are based on the time frame under consideration. With a longer planning horizon, more and more fixed costs become variable. Fixed costs represent costs that are incurred annually regardless of the level of production, such as depreciation, taxes, insurance. In contrast, variable costs fluctuate with the production level. Examples are labor, energy, and feed costs.

Specification of fixed and variable costs depends on the time frame under consideration. Both fixed and variable costs are associated with any given production year. However, in deciding whether or not to produce, decisionmakers consider only variable costs. As long as a production enterprise will yield sufficient revenues to cover variable costs and a portion of the fixed costs, production should continue. The alternative of idling the resources would result in no revenues being generated to offset the fixed costs.

As the time span increases, the producer is able to make changes, whereas in the short run the producer has fewer alternatives and becomes locked into a particular production activity. In a longer planning period, some of the previously fixed costs become variable costs and in the very long run, all costs become variable. In other words, over a long enough planning period, fixed assets can be completely depreciated or abandoned.

An important point to remember is that there are tradeoffs between fixed capital and variable capital resources such as equipment and labor. Capital can usually be readily substituted for labor. However, once capital is invested in durable equipment, the tradeoffs become difficult and are almost impossible in the short run. Consequently, as farmers buy more equipment to reduce labor, their flexibility for meeting changing economic conditions is reduced.

The allocation of resources between livestock production and crop activities requires tradeoffs between various inputs or practices. The goal of farm managers is to allocate resources efficiently among the varying possibilities that exist in the farm enterprise. They need to reach a proper balance between equipment use and labor, between forage and grain and feed

ration, and between manure and commercial fertilizer as a plant nutrient.

Opportunity Costs

Farmers continually seek to use their limited resources in the most productive manner. Applying the concept of opportunity costs insures that resources are used in the most economically efficient manner. The opportunity cost is the income or return foregone by using a resource somewhere other than for its most profitable purpose. Profits will be greatest when each unit of land, labor, and capital is used where it will add the greatest return. Stated differently, optimum use of limited resources exists when resources are organized such that any change in the organization of capital, labor, or acreage inputs will reduce income.

The opportunity costs principle can be demonstrated with an example from hog production. A hog producer who has been applying manure on corn fields receives an offer of $5 a ton from a neighbor. The producer figures that $3 a ton can be cleared after a deduction for transportation costs. Sale of 200 tons would return $600, but it would take $700 worth of commercial fertilizer to replace the hog manure and still maintain production levels. By selling the manure, the producer incurs a $700 opportunity cost. As the return from selling the manure was $600, there would be a net loss of $100 due to foregone opportunities.

One can also use the concept of opportunity costs for comparing practices and enterprises on the farm as a whole. The concept applies to all investment opportunities. It can also be used to measure the cost of environmental regulation on the farm.

Budgeting

Two forms of budgeting can be used for incorporating economic concepts into problem analysis--complete budgeting and partial budgeting. Complete budgeting refers to a total accounting plan for whole farm or for all decisions in a single enterprise. For example, complete farm budgeting would estimate all crop and livestock producing methods, costs, and returns. It would include all viable alternatives for the farm organization. Many farm management decisions affect only a small portion of the entire farm operation and do not require all the information for a complete farm budget. Farmers can use partial budgeting to evaluate only those operations or input levels that will be affected by the decision.

Partial budgeting is the most common and the simplest form of budgeting for economic decisionmaking. The crucial element in preparing a partial budget is identifying the items that change due to an adjustment. For example, a livestock operator considering changing waste management systems is unlikely to make

a complete change in livestock enterprise. Feed costs, veterinary bills, building costs, and machinery and equipment costs not associated with waste management will remain unchanged. However, the costs of waste disposal may well change, as might the cost of producing crops if the manure is spread on the land. Thus, these items should be included in the partial budget. Similarly, if an adjustment in the system increases the amount of nitrogen available from manure, then the use of commercial fertilizer might also be examined in the partial budget.

In evaluating alternative investments, farmers can set up partial budgeting to identify the returns and costs for each alternative. Then they can identify the differences in costs between alternatives. Table 2 presents an example of a partial budget format. This format can be modified to fit a variety of situations, but it illustrates the changing costs and returns to consider in partial budgeting.

Amortization

A livestock producer evaluating an investment in waste handling equipment wants to know the annual cost of repaying the initial investment. Using the total amount of the investment, the life of the investment, and the cost of money (interest rate), the producer can determine the annual payment to repay the investment and include it in the budget development. The producer can use the amortization factors presented in appendix table 11 to determine this annual repayment amount. An example would be determining the annual costs to repay a $4,000 loan to purchase a liquid manure spreader. Assuming the loan is to be repaid in 5 years and that the cost of money is 10 percent, an amortization factor of 0.2638 is taken from appendix table 11. Multiplying the investment ($4,000) by the amortization factor (0.2638) gives the annual repayment amount, or $1,055. This is the annual payment necessary to repay the amount borrowed, plus interest.

The following sections of our manual illustrate how one can use economic tools as aids to decisionmaking in a variety of livestock production situations. Although our discussion of each of the principles is not comprehensive, we provide enough information to develop examples. We tried to insure that the examples contained reasonable technical information, but our overriding purpose was to illustrate the use of the economic concepts.

We did not attempt to cover all feasible livestock production combinations, but we did try to be realistic by discussing typical livestock production systems in different geographic areas. The costs of equipment used in the budgets are representative of the 1978-79 period.

Table 2--Partial budget format for evaluating waste management systems, single enterprise operation

Item	Cost
	Dollars 1/
Additional capital outlays:	
New manure control structures	15,000
New manure handling equipment	10,000
Subtotal	25,000
Salvage value (if any)	5,000
Fixed investment to be amortized at 12-percent interest for 10 years	20,000
Annual ownership costs:	
Annual amortized cost (principal and interest), $20,000 x 0.1770	3,540
Taxes	200
Insurance	200
Total annual ownership costs	3,940
Annual operating costs:	
Labor	500
Fuel	150
Electricity	50
Chemicals	0
Total annual operating cost	700
Total annual costs	4,640
Benefits:	
Increased value of residues from new handling system (if any)	0
Total new annual cost increase (decrease)	4,640

1/ Dollar values are presented only to help the reader follow the budget format; they do not reflect actual costs of any waste management system.

The selected manure handling options were specific to a geographic area, and we evaluated alternative systems in terms of suitability of capital and labor availability. We identified tradeoffs between capital and labor requirements when pertinent to normal farm operations.

Our analysis makes the following assumptions:

1. There are no constraints on the availability of labor and capital.

2. Farmers will continue to operate and sell their products as in the past. Markets for outputs and prices are assumed to remain the same.

3. There are no limitations placed on energy resources available for any of the options.

4. No distinction is made between family labor and hired labor.

5. An interest rate of 12 percent is used for all financial calculations.

6. The suppliers of equipment for the options evaluated are assumed readily available for installing and servicing the systems.

7. The tractors needed to operate pumps are assumed available as part of the equipment complement used in the total farming operation. The sizes available are consistent with the requirements of the waste management alternatives evaluated.

8. For those options where soil incorporation is identified, plowdown is the only tillage practice examined. No related impacts on soil erosion are considered.

LAKE STATES DAIRY FARM

Consider the case of a dairy farmer in the Lake States. Water quality objectives have been set which suggest that to avoid runoff no manure be applied to frozen ground. To meet this goal, the farmer needs a 6-month manure storage capability. We illustrate how the dairy farmer can use budgeting to evaluate storage alternatives to meet both water quality and profit objectives.

The dairy farmer is milking 54 cows on a 160-acre farm. The farm is equipped with a stanchion barn and gutter cleaner. Manure is usually spread daily. The area is characterized by gently sloping hills with a general elevation of 500-1,000 feet.

Average annual precipitation is 30-32 inches, occurring mostly in late spring and early summer. Annual temperatures range from -25° to 95° F. with an average growing season of 140-170 days. The farm has 73 acres of alfalfa, 44 acres of corn silage, and 28 acres of corn for grain to complement the dairy enterprise.

The first task is to define some viable options to daily spreading. The dairy farmer can obtain assistance by consulting with an SCS representative, a county extension office, sales representatives, local equipment dealers, and magazines. In this example, we selected two options for budget analysis and for comparison with daily spreading: (1) 180-day pit storage, piston pump, twice-a-year solid spreading and (2) 180-day pit storage, stacker elevator, twice-a-year solid spreading. We could have analyzed other variations, such as using a tank wagon with a pump-type unloader for field application. For our analysis, we assumed the material was solid enough for spreader application. One should remember that each type of manure management system has a distinct effect on manure quantity and quality and that generalizations will not apply across all types of systems and geographic regions.

By using a partial budget, the dairy farmer can identify the costs of alternative systems in terms of additional capital requirements, annual ownership costs, and annual operating costs. Then, the estimated returns from nutrients in the manure can be added to the analysis, yielding an estimate of annual increases or decreases in total annual costs associated with each alternative. The easiest way to approach the problem of determining and comparing costs is to consider the equipment needs. Table 3 shows the equipment needs for each option in this example. As the dairy farmer is interested only in the additional costs of each option, equipment common to all options need not be considered. As the method of collection will be identical for each of the three alternatives in this example, that cost can be omitted from the analysis. The other tasks require different equipment, whose costs will be compared in the analysis.

Using information from appendix table 10, the dairy farmer can estimate capital costs for each alternative. Estimates of operating costs can then be added to determine total costs. The figures in table 4 contain capital or fixed costs and variable costs. The fixed costs include interest and depreciation. The variable costs include labor, fuel, repair, and maintenance costs.

Transferring Manure from Barn to Storage

The existing system, daily spreading, has no storage and hence no costs for transferring manure from the barn to storage.

Table 3--Equipment and labor required for solid-handling manure management options, 54-cow dairy herd with stanchion barn, Lake States

Task	Existing system	Option 1	Option 2
Collection	Gutter cleaner	Gutter cleaner	Gutter cleaner
Transfer to storage	None	Piston pump	Stacker elevator
Storage	None	Earthen basin w/concrete floor	Earthen basin w/concrete floor
Transfer from storage	None	Tractor w/front-end loader	Tractor w/front-end loader
Application	Daily solid spreader	Twice-a-year solid spreader	Twice-a-year solid spreader
Total labor requirements (hours)	210	145	190

Note: Existing system = daily field spreading; option 1 = 180-day pit storage, piston pump, twice-a-year solid spreading; option 2 = 180-day pit storage, stacker elevator, twice-a-year solid spreading.

However, options 1 and 2 do require storage and include transfer costs that must be computed.

Option 1 includes a piston pump powered by a 10-hp electric motor. The initial price of the piston pump is $8,000, fully installed with all necessary accessories. If the pump operates the same number of hours as the gutter cleaner, the dairy farmer estimates the pump will operate approximately 200 hours per year for a 54-cow stanchion barn. This assumes a 0.3-minute per cow cleaning rate and a barn cleaning twice daily. Assuming the 10-hp motor uses 10 kW per hour of operation at 4 cents per kWh, the electricity costs are $80 per year. Repair and maintenance costs are assumed to be $1.50 per hour of operation, making the annual costs $300. The only labor the pump involves is turning on the switch and checking it occasionally for proper operation. This takes an estimated 5 hours per year and costs $17.50 per year, at $3.50 per hour. Annual ownership costs are $1,826 and annual operating costs are

Table 4--Partial budget analysis of waste management options, 54-cow dairy herd, Lakes States 1/

Item	Existing	Option 1	Option 2
		Dollars	
Additional capital outlays: 2/			
Piston pump	--	8,000	--
Stacker elevator (30 ft.)	--	--	2,400
Earth basin with concrete floor (bunker)	--	4,350	4,350
Front-end loader	--	2,000	2,000
Subtotal		14,350	8,750
Less salvage value	--	6,015	3,155
Fixed investment to be amortized at 12 percent for 7 years	3/0	8,335	5,595
Annual ownership costs:			
Fixed investment x amortization factor (0.2191)	--	1,826	1,225
Annual operating costs:			
Labor at $3.50/hr.			
Transfer to storage	0	18	175
Transfer from storage to fields	735	490	490
Electricity at $0.04/kWh			
Transfer to storage	0	80	12
Fuel and lubrication 4/			
Transfer from storage to fields	567	460	460
Repair and maintenance			
Transfer to storage	0	300	100
Transfer from storage to fields at $1.25/hr.	228	116	116
Total annual operating costs	1,530	1,464	1,353
Total increase in annual costs	1,530	3,290	2,578
Return from manure as plant nutrients	2,160	2,480	2,350
Net change in annual costs	-630	810	228

-- = Not applicable.

1/ Existing = daily field spreading: option 1 = 180-day pit storage, piston pump, twice-a-year spreading; option 2 = 180-day pit storage, stacker elevator, twice-a-year spreading.

2/ Based on costs in appendix table 10.

3/ A manure spreader is a common investment to all options and is, therefore, omitted here.

4/ Diesel at $1/gal. plus 15 percent for lubricants.

$1,464. The estimated additional annual cost for option 1 is $3,290.

In option 2 manure is transferred to storage by a stacker elevator. The stacker elevator has an initial cost of $2,400. The stacker is powered by a 1-1/2 hp motor using 1-1/2 kW per hour of operation. Like the piston pump, the stacker operates the same number of hours as the gutter cleaner. This results in approximately 200 hours of operation per year. Based on a comparison of the cost of a stacker elevator with the piston pump, it is assumed that repairs and maintenance cost $0.50 per hour.

The stacker elevator requires much more labor when compared with a transfer pump, especially in the Lake States area where harsh winter temperatures prevail. Each time the barn is cleaned, the stacker should be inspected to make sure the chain and slats are free from ice. Many times they will not be and will require a few taps to loosen the ice. This procedure is estimated to take approximately 40 hours per year. The stacker will need to be moved to evenly distribute the manure in the stack, which is estimated to take 0.05 hours for each hour of operation, or 10 hours annually. The total increase in annual costs for option 2 is $2,578.

Manure Storage

The existing system does not require storage facilities; therefore, no costs are incurred. However, both options 1 and 2 require storage structures. In this example, the storage structure is an earthen basin or pit with a concrete floor. (Alternatively, a bunker type structure might be used.)

Before the dairy farmer can calculate the cost of the storage structure, the size of the storage structure must be determined. A 1,400-pound dairy cow produces approximately 1.85 cubic feet of manure per day (app. table 1). One should also include bedding in calculating the figure for total waste. A stanchion barn using chopped straw requires about 8 pounds per day for a 1,400-pound animal. The volume of straw in the manure can be determined from the formula in appendix table 5. For the sample dairy, 1.00 cubic foot per head per day was assumed. Total manure volume (raw manure plus bedding) is 2.85 cubic feet per day per animal (1.85 + 1.00). Multiplying the number of cows and days of required storage by 2.85 yields the storage volume. (This will likely result in a generous volume estimate due to the absorbent capacity of the bedding.) The sample situation is assumed to include 54 cows and projects a 180-day storage capacity, thus making the volume required approximately 27,702 cubic feet, or 1,026 cubic yards.

Excavation costs for an earthen basin were assumed to be $1 per cubic yard, or $1,026 for this example. If the pit averages 5 feet in depth, a 5,540 square foot, 6-inch thick concrete base is needed and will cost $3,324, based on concrete prices of $0.60 per square foot at 6-inch thickness. Total construction cost of the storage basin is $4,350.

Transferring Manure from Storage to Field

The only transfer activity for the existing system is daily hauling and spreading the manure. The time required to spread one load daily is slightly more than one-half hour, which includes starting the tractor, attaching and positioning the spreader, travel time, spreading time, and unhitching. If the application site is 1,500 feet from the barn, the fuel consumption for a tractor pulling a 220-cubic foot spreader is approximately 0.85 gallons per load. Hauling 365 loads per year consumes 310 gallons of fuel for spreading and requires 210 hours of labor. In addition to hauling and spreading, the tractor probably consumes another 0.5 gallons per day due to startup and idling. Annual fuel requirements for daily spreading are 493 gallons, or $493 if diesel fuel is priced at $1 per gallon; oil and lubrication costs are an additional 15 percent, or $74. Annual labor costs are $735 at $3.50 per hour. Repair costs for the tractor and spreader are $1.25 per hour. Although the tractor and spreader are not always in operation the entire half hour, the dairy farmer should probably assume this figure includes the extra abuse that daily spreading places on equipment. Annual repair and maintenance costs for the tractor and spreader are $228. The total cost for daily spreading is approximately $1,530 per year.

Options 1 and 2 use the same type of storage and have identical costs. Both require a tractor with a front-end loader to get the manure from the storage area into the spreader. Labor and fuel requirements for loading, transporting, and spreading manure are taken from appendix tables 7 and 9. Annual repair and maintenance costs for loading, transporting, and spreading manure are presented in appendix table 8.

It was previously determined that a 6-month accumulation of manure occupies 27,700 cubic feet. Using tables 5 through 10 of the appendix, one can compute variable costs for manure handling from storage to land application for options 1 and 2. A 220-cubic foot spreader with a 1,500-foot travel distance from storage area to application site is cited in the example. Fuel is priced at $1 per gallon, plus 15 percent for lubrication and oil changes. Labor is priced at $3.50 per hour. From the appendix tables, one can determine that 27,700 cubic feet of manure require about 70 hours labor and 200 gallons of fuel for each semiannual spreading. These figures are doubled for a 12-month period. Annual labor is thus 140 hours and

fuel use 400 gallons (plus oil and lubrication), yielding annual costs of $490 and $460, respectively. Repair and maintenance costs are approximately $58 for the application of 27,700 cubic feet of manure each 6 months, or $116 annually (app. table 8).

Estimating Nutrient Value of Manure

The value of available nutrients is an important factor in evaluating alternative waste management systems. Table 4 shows the "return from manure as plant nutrients." Estimations of this value are based on three key assumptions: (1) the total nutrients in the fresh manure, (2) the loss of nutrients in the handling and storage phases which determines the nutrients available for crop production, and (3) the value of these available nutrients as commercial fertilizer substitutes.

Nitrogen, phosphorus, potassium, and other minerals are contained in manure. Nitrogen is the most volatile of these elements and is generally considered the limiting nutrient both in crop growth on land and algae growth in water. The total production of nutrients in animal waste can be estimated, based on the type and size of livestock. As minerals in fresh manure are subject to losses in storage and application, adjustments are needed to estimate amounts available for plant consumption.

Table 5 presents estimated nutrient losses and plant availability for the three manure management systems considered by the dairy farmer. Nitrogen available for crop use varies from 75 pounds to 125 pounds per animal per year. Option 1, manure pit storage, provides greatest nitrogen savings.

Table 6 summarizes the total amounts of nitrogen (N), phosphorus pentoxide (P_2O_5), and potassium oxide (K_2O) available to plants after all but runoff losses are taken into account. The estimates of available P_2O_5 and K_2O for each animal are based on appendix table 1. The estimated losses of P_2O_5 and K_2O--10 and 15 percent, respectively--are based on appendix table 2.

The annual nutrient values on a per-cow basis are approximately $40, $46-48, and $43-45, respectively, for the existing system and for options 1 and 2. This estimate assumes that the nutrients in wastes are being substituted for those that would otherwise be purchased. The key determinant is the time between spreading and soil incorporation. This example assumes incorporation within 7 days. Table 6 summarizes nutrient availability and value for the entire herd.

Other Factors

Total labor and peak time labor requirements are an important consideration when one compares the two alternatives with the existing system. Of the situations analyzed, daily spreading

Table 5--Production and losses of nutrients for Lake States dairy herd, by waste management option and frequency of application

Item	Existing system	Option 1			Option 2		
	7 or more 1/	1	4	7 or more	1	4	7 or more
	Pounds/dairy cow/year						
Total nitrogen 2/	208	208	208	208	208	208	208
Storage loss 3/	104	52	52	52	73	73	73
Application loss as free ammonia 4/	10	0	8	16	0	7	14
Denitrification loss as N_2 5/	19	31	30	28	27	26	24
Total nitrogen loss	133	83	90	96	100	106	111
Total nitrogen remaining for crop use	75	125	118	112	104	102	97
P_2O_5 available for crop use 6/	76	76	76	76	76	76	76
K_2O available for plant use 6/	143	143	143	143	143	143	143

Note: Existing system = daily surface spread; option 1 = manure pit storage fed from bottom by transfer pump; and option 2 = manure pit storage fed from top by stacker elevator.

1/ Numbers indicate days between application and incorporation.

2/ Calculated from appendix table 1; 365 days x 0.57 pound of nitrogen per day per 1,400-pound dairy cow.

3/ The storage loss for daily surface spread may seem far too great at first glance, as most sources state that there is a 20-percent loss for this option. In this instance, the land is the storage area, as most of the manure nitrogen is neither incorporated nor used for several months. Nitrogen storage losses for options 1 and 2 are estimated at 25 and 35 percent, respectively. Appendix table 2 presents information that can be used to approximate storage and spreading losses for the major nutrients.

4/ Appendix table 3 was used to calculate volatilization losses for a cool, moist soil.

5/ Appendix table 4 was used to calculate denitrification losses for a moderately well-drained soil.

6/ Each animal unit produces 85 pounds of P_2O_5 and 168 pounds of K_2O. The phosphorus and potassium losses are the same for all three options--10 and 15 percent, respectively.

Table 6--Nutrient availability and value of waste, 54-cow dairy herd, Lake States 1/

Item	Existing system	Option 1	Option 2
		Pounds per year	
Nutrients available: 2/			
Nitrogen (N)	4,050	6,048	5,238
Phosphorus (P_2O_5)	4,104	4,104	4,104
Potash (K_2O)	7,722	7,722	7,722
		Dollars	
Value 3/	2,160	2,480	2,350

1/ Average cow weight is 1,400 pounds.
2/ Soil incorporation takes place within 7 days after application.
3/ Nutrient values per pound: 16 cents for nitrogen, 18 cents for phosphorus, and 10 cents for potash. Nutrients valued as plant-available during the growing season. Minor elements, such as calcium and manganese, are not valued.

requires the greatest amount of total labor, followed in order by option 2 (storage with stacker elevator) and option 1 (storage with piston pump). In contrast, the existing system (daily spread) requires no peak-time labor, but options 1 and 2 do. Peak-time labor demands occur when large blocks of labor are required within short time periods for critical farm operations, such as during spring planting and fall harvesting periods. Concentrating waste management activities in these periods may have a high opportunity cost. For example, a rule of thumb in the Corn Belt is that corn yields decline by 1 bushel per acre for every day planting is delayed beyond May 1.

For most of the year, daily spreading does not require peak-time labor, although it does require a greater number of total hours. Some of these hours involve being outdoors during unpleasant times, such as in snowstorms or cold spells. Many dairy farmers may well prefer to select a management option that costs more, but eliminates the chore of daily spreading.

The economic cost is clearly not the only decision variable the farmer may want to consider.

Fuel requirements will unquestionably become a more important decision variable for farmers, considering the potential shortages and increased costs. In the above example, fuel is a relatively small proportion of total expenditures, and even doubling fuel costs would not significantly change total costs. This example may not correspond to fuel costs in other analyses.

The higher costs associated with options 1 and 2 are due mainly to the additional capital investment required. Storage structures and equipment are expensive, and dairy farmers cannot hope to recapture all extra costs from the increased plant nutrient value of the manure.

In the current money market, obtaining capital is expensive. In our Lake States example, the interest rate used for borrowed money was 12 percent. If the dairy farmer has to pay higher interest costs, the costs of options 1 and 2 will be considerably higher. Dairy farmers and environmental planners should keep in mind that capital is often a serious constraint on the construction of capital-intensive management systems. Capital used for one activity means that it will not be available for others, such as farm or enterprise expansion.

Summary of Costs

Cost data for the existing system and options 1 and 2 were summarized in table 4. Some costs are common to all and are, therefore, not included--for example, gutter cleaning and investment in a manure spreader. Daily spreading is the least cost alternative, the only option where nutrient value exceeds costs. Option 2 is the least costly alternative to meet environmental goals, because it minimizes both total and net cost increases. The higher costs of options 1 and 2 are due almost entirely to the additional capital investments. The nutrient value of the wastes is approximately the same for options 1 and 2.

Our analysis points out the nature of the problem farmers face in meeting environmental regulations, such as stopping land spreading in the winter. Meeting regulations comes at a cost that will be borne directly or be shared through Federal, State, or local cost-sharing programs.

SOUTHWESTERN DAIRY FARM

In this example, a dairy farmer in the Southwest is faced with the need to reduce the pollution potential from drylot runoff. This pollution potential can be substantially reduced by the use of a settling channel and holding pond.

The dairy farm has 280 cows on a drylot with a milking parlor system. Animal waste is allowed to accumulate on the lot and is loaded into a solid spreader for field application. This is usually done during the winter months when labor is not tied up with cropping operations. Winter spreading does not create a runoff problem in this situation as temperatures are mild and the ground is not frozen. Climatic conditions are arid and warm to hot, and precipitation is usually 10-12 inches, with summer temperatures varying from 65° to 93° F. and winter temperatures from 30° to 54° F.

The dairy farmer wants to know the costs and returns associated with adding a settling channel and collection pond to current facilities. Partial budgeting will help answer these questions. One should estimate runoff and required storage capacity and then estimate the costs of this capacity. As some solids can be recovered from the settling channel and used on cropland along with lot accumulations as nutrient sources for crop production, the potential benefits need to be considered in this analysis.

Estimating Drylot Runoff

In all analyses of this type, one must consider several physical relationships and review the data before assessing either costs or returns. These factors include lot size, annual precipitation, manure production per animal, and number of animals. Dairy farmers are aware of some of these data needs from their farm records. For example, the dairy farmer knows there are 280 cows, each weighing an average of 1,400 pounds. The lot was designed and built to provide 600 square feet per cow and is unpaved; it totals 168,000 square feet.

The next step is to estimate the total solids in the runoff from the drylot. The local SCS and university extension offices can provide guidelines for estimating runoff and transported solids for specific animal and soil types. The farmer can calculate total annual feedlot runoff by multiplying the following factors: (a) square feet in drylot, (b) average annual precipitation in feet, and (c) constant factor of 30-percent runoff for unpaved lots (80-percent runoff for paved lots). The annual runoff for the drylot is 50,400 cubic feet (168,000 x 1 x 0.3).

Total solids in the runoff have been estimated to vary from 0.3 to 1.75 percent by weight, depending on intensity of precipitation and moisture deficiency in the soil. Water storage in soil-manure mixture can be appreciable. After long dry summer periods, drylots can absorb up to 1 inch of rainfall without runoff. In this example, a midrange of 1 percent total solids by weight is assumed. Total solids from runoff are

estimated at 504 cubic feet on the drylot and 1,344 cubic feet on the paved lot.

Estimating Construction Costs

Several designs for building settling basins or channels are available. Dairy farmers should consult their own extension agricultural engineers for plans and designs for their individual sites. The settling channel in the Southwest example is designed to be 315 feet long, 4 feet deep, and 10 feet wide (a capacity of 467 cubic yards). The channel is drained with a standpipe to the storage pond. In our example, the size of the storage pond is based on the volume of runoff from 9 inches of precipitation. On the average, the storage structure is assumed to be half full and has the capacity to store the runoff from a 10-year, 24-hour storm event. In addition, the storage pond was designed to have 1.5-foot extra capacity above the maximum water storage level. The extra depth insures that wave action will not damage the structure and cause mechanical failure. The construction of a 100 x 126 x 4.5 foot structure would require moving 2,100 yards of earth.

The producer may need to consider the cost of dewatering the storage pond. In the Southwest, however, dewatering can be taken care of inexpensively by evaporation, provided that the surface area of the pond is large enough. Or, the dairy farmer may want to consider using the water for irrigating crops or pasture. Our analysis does not consider costs or benefits attributed to dewatering for irrigation.

Once a year during the dry period, solids are scraped from the settling channel and spread on the land. This job usually takes about 2 hours, requiring about 8 gallons of diesel, plus lube. The estimated annual operating costs are $16. Fixed costs on tractors and equipment are not included, as these are charged to crop enterprises.

Estimating Costs and Benefits

Table 7 shows the additional costs and benefits associated with building the settling channel and pond. The nutrients captured in the settling channel represent the principal benefits the dairy farmer receives from controlling runoff from the drylot. In this example, the dairy farmer estimated that there were 31,300 pounds (504 ft^3 x 62 lb/ft^3) of dry solids in the runoff.

The dairy farmer must next analyze the nutrients contained in the dry solids. A good method is to send samples of the settled solids to a laboratory for tests for nutrients and salts. Runoff contains soluble salts and must be carefully managed when used as a fertilizer to avoid potential damage to the soil or harm to crops, especially in areas where salt concentrations in soils are already high.

Table 7--Partial budget format for evaluating waste management systems, Southwest dairy herd

Item	Option 1/
	Dollars
Additional capital outlays:	
Settling channel construction	470.00
Storage pond construction	2,100.00
8-in. standpipe	100.00
Subtotal	2,670.00
Salvage value	1,335.00
Fixed investment to be amortized at 12 percent for 7 years	1,335.00
Annual fixed costs:	
Fixed investment x amortization factor (0.2191)	292.50
Annual operating costs: 2/	
Labor at $3.50/hr.	7.00
Fuel at $1/gal. + 15 percent for oil and lubricants	9.20
Total annual operating costs	16.20
Total increase in annual costs	308.70
Return from manure as plant nutrients	219.00
Net change in annual costs	+89.70

1/ The costs and returns associated with adding a settling channel and collection pond to current facilities.
2/ Costs for scraping settling channel.

Assuming the nutrient content of the settled solids is the same as manure scraped from the drylot, approximately 300 pounds of nitrogen, 450 pounds of P_2O_5, and 900 pounds of K_2O would be collected from the runoff. This assumes that 100 percent of the solids can be recovered and the nutrients are available to the plant in a usable form. If the nutrients are priced at 16, 18, and 10 cents a pound, respectively, the value of the dry solids captured from the settling channel is $219.

After comparing the increase in annual costs with the value of estimated nutrients recovered, the farmer finds that the net annual increase in cost of the proposed changes is approximately $90 per year, after accounting for the value of additional nutrients saved.

SOUTHEASTERN DAIRY FARM

The following example is for a typical 75-cow milking herd in the Southeast. The dairy farmer is remodeling existing facilities and wants to compare the respective costs of solid and liquid handling systems.

The region has a hot and humid climate. The ground almost never freezes. Average annual precipitation varies between 50 and 60 inches. Typically, cows are kept in confinement in loafing sheds and milked in a parlor. Manure is scraped, hauled, and spread daily. Over the years, some dairy farmers have started to switch to liquid systems with lagoons. Lagoons are usually dewatered by use of high pressure pumps combined with an irrigation system. With a lagoon system, barns can be cleaned with either an automatic flush system or a pressure hose system.

Our example focuses on changes in the waste handling system for the loafing area and milking parlors. A dairy farmer wants to compare a solid handling system with a liquid handling system, particularly their respective requirements for investment and labor. As the farmer is interested only in comparing alternative waste handling facilities, the costs of other components of the loafing shed need not be evaluated. Thus, the comparison will focus on the following options:

1. Solid-waste handling system, with daily scraping, hauling, and spreading;

2. Liquid-waste handling, with daily scraping, holding tank storage, tank hauling, and injection; and

3. Liquid-waste handling, with twice-daily automatic flush system, lagoon storage, and cropland irrigation.

Estimating Nutrient Value of Manure

Manure production from the 75-cow dairy is estimated at about 1,574 tons per year. A 1,400-pound dairy cow produces 0.57 pounds of nitrogen, 0.23 pounds of P_2O_5, and 0.46 pounds of K_2O per day (app. table 1). Total annual nutrient production from the 75-cow milking herd is approximately 15,600 pounds of nitrogen, 6,290 pounds of P_2O_5, and 12,590 pounds of K_2O. Nutrient losses occur in the collection, storage, and land application phases of management. Good manure management can help minimize losses and simultaneously protect the quality of streams and lakes. One can estimate losses by using appendix tables 2, 3, and 4. Table 8 presents data on nutrient production, losses, and the value of nutrients available for plants for the Southeastern dairy example.

Estimating Costs and Benefits

Table 9 summarizes costs and returns for the three systems considered. Using appendix tables 1, 7, 8, and 9, we estimated annual operating costs for hauling and applying manure. The estimated volume of manure was approximately 51,000 cubic feet (75 cows x 1.85 x 365). By extrapolation from appendix table 9, approximately 152 hours of labor were required to load, haul, and spread this manure with a 220-cubic foot spreader, assuming a travel distance of 2,500 feet (option 1). If a 3,000-gallon tank spreader is used, approximately 61 hours of labor are required (option 2). Based on appendix table 7, the fuel requirements for hauling and spreading are 434 gallons for option 1 and 463 gallons for option 2. An additional 0.5 gallon of fuel per day is assumed for scraping, tractor startup, and idling on those days when manure is hauled and spread--an additional 185 gallons for option 1 and an additional 100 gallons for option 2. Option 1, the conventional scrape, haul, and spread solid manure system, is the least costly alternative, if one ignores the impact of environmental costs or regulations. The higher costs of options 2 and 3 are due to the higher investment requirements and, in the case of option 3, to the greater loss of nutrients.

If the dairy farmer's only constraint is to minimize investment cost and labor, option 1 is the system to select. However, option 3's waste handling system requires 62 fewer labor hours annually than does option 1's. The dairy farmer must decide whether the labor savings is worth the added investment. If the opportunity cost of going to the liquid flush system is divided by the labor saved (($4,167 - $2,633) ÷ 63), one can see that the labor savings comes at a cost of $25.75 per hour. It would clearly be less costly to select option 1 and hire the additional labor at a going rate of $3.50 per hour. However, there are environmental benefits associated with options 2 and 3 that the farmer must consider in making the final selection.

Table 8--Nutrient production, losses, and value, 75-cow dairy herd, Southeast

Item	Option 1			Option 2			Option 3		
	Nitrogen	P_2O_5	K_2O	Nitrogen	P_2O_5	K_2O	Nitrogen	P_2O_5	K_2O
	Pounds								
Nutrient production	15,600	6,290	12,590	15,600	6,290	12,590	15,600	6,290	12,590
Nutrient losses:									
Storage 1/	7,800	630	1,260	4,680	314	630	13,260	3,145	5,040
Volatilization 2/	780	--	--	1,092	--	--	470	--	--
Denitrification 3/	1,560	--	--	2,184	--	--	470	--	--
Total losses	10,140	630	1,260	7,956	314	630	14,200	3,145	5,040
Nutrient available for plant use	5,460	5,660	11,330	7,644	5,976	11,960	1,400	3,145	7,550
	Dollars								
Nutrient value per year 4/	874	1,019	1,133	1,223	1,075	1,196	224	566	755

-- = Not applicable.

Note: Option 1 = solid-waste handling, daily scraping, hauling and spreading; option 2 = liquid-waste handling, daily scraping, holding tank storage, hauling, and injection; option 3 = liquid-waste handling, twice-daily automatic flush system, storage pond, cropland irrigation.

1/ Calculated from percentage of storage losses shown in appendix table 2.

2/ Calculated from percentage of volatilization loss for warm moist soil (app. table 3).

3/ Calculated from percentage of loss by denitrification for moderately well-drained soil (app. table 4).

4/ Nitrogen valued at 16 cents/pound, P_2O_5 at 18 cents/pound, and K_2O at 10 cents/pound.

Table 9--Partial budget analysis of waste management options, 75-cow dairy herd, Southeast

Item	Option 1 1/	Option 2 1/	Option 3 1/
		Dollars	
Additional capital outlays:			
Manure spreader	3,200	--	--
Tractor scraper	500	500	--
Front-end loader	2,000	--	--
Spreader tank (3,000 gal.)	--	7,000	--
Injectors (2)	--	1,200	--
Holding tank	--	6,300	--
Flush tanks (2)	--	--	2,500
Earthen lagoon	--	--	5,500
Traveling gun irrigator	--	--	5,000
High pressure centrifugal pump, with chopper	--	--	5,000
1,000-ft. aluminum pipe	--	--	5,000
Subtotal	5,700	15,000	23,000
Less salvage value	1,245	4,155	9,250
Investment for amortization at 12 percent for 7 years	4,455	10,845	13,750
Annual ownership costs:			
Fixed investment x amortization factor (0.2191)	976	2,376	3,013
Annual operating costs:			
Labor at $3.50/hr. 2/	745	424	529
Fuel and lubricants 3/	712	647	125
Repair and maintenance 4/	200	225	500
Total annual operating costs	1,657	1,296	1,154
Increase in annual costs	2,633	3,672	4,167
Value of nutrients in manure	3,026	3,494	1,545
Net change in annual costs	-393	+178	+2,622

-- = Not applicable.

1/ Option 1 = solid-waste handling, daily scraping, hauling and spreading; option 2 = liquid-waste handling, daily scraping, holding tank storage, hauling, and injection; option 3 = liquid-waste handling, twice-daily automatic flush system, storage pond, cropland irrigation.

2/ The 213-hr. labor requirement for option 1 is based on 152 hrs. (app. table 9), plus an additional 60 hrs. assumed for scraping and miscellaneous activities; the 121 hrs. for option 2 are based on 61 hrs. (app. table 9), plus 60 additional hrs.; option 3 uses 151 hrs. of labor, 104 hrs. for cleaning, and the remainder for irrigation and other activities.

3/ Fuel use is assumed to be 619 gal. for option 1, and 563 gal. for option 2. Costs are based on $1/gal., plus 15 percent for lubricants and oil. Energy costs for option 3 are estimated to be $125.

4/ Repairs for options 1 and 2 are based on appendix table 8, plus $75 assumed for scraper repairs. Repair costs for option 3 are assumed to be about $500.

CORN BELT HOG OPERATION

In our example, we discuss alternatives for Corn Belt hog farmers who must change their operations to meet regulations that forbid manure application on frozen ground. It illustrates problems that a typical hog farm might encounter.

The principle crops are corn and soybeans, which are produced on highly productive prairie soils. The topography is rolling to slightly undulating. Summers are warm, and winters are cold and humid.

The operation markets about 650 head of slaughter hogs per year. The central farrow house has solid floors, and the hogs finish on drylots. Sows and pigs are kept in the house 6-8 weeks before the pigs are weaned and moved to the growing house for an additional 6-8 weeks. Straw bedding is used in both the farrowing and growing house, and all manure is handled as a solid. Both the farrowing house and the growing house are cleaned daily when in use. Manure is spread year round whenever the spreader fills, usually every 4-6 days.

When the pigs reach 100-120 pounds, they are moved to the drylot for finishing. The drylot is partially covered, but unpaved. There are currently no drains or gutters for either liquid waste or for rain and snow runoff. The drylot is scraped once or twice per year as labor availability permits.

Let us assume that after considerable study and planning, the State Department of Environmental Quality has decided to implement regulations that forbid manure application on frozen ground. The Department also recommends that farmers have 6-months manure storage capacity, plowdown manure as soon as possible after application, and install runoff-control facilities on exposed lots that would be capable of handling the runoff from a 10-year, 24-hour storm event.

Hog producers must now decide how to comply with the current environmental regulations, as well as prepare for possible future regulations. A good initial strategy would be for individual producers to consult their own county extension agent, the Soil Conservation Service, the State Extension Agricultural Engineer, and reliable equipment dealers. Again, each farm situation is unique and requires individual analysis for farmers to reach acceptable solutions.

A farmer keeps 40 sows, each of which farrows twice a year, with four farrowing periods during the year. To estimate the volume of manure that must be managed annually, the farmer completes the thought process summarized in table 10: (1) estimates the number of days each animal spent in the various stages of production during the year, (2) applies the factors

Table 10--Annual manure production, Corn Belt hog operation

Production phase	Cycles per year	Days per cycle	Number of animals in each cycle	Manure production	
				Pounds/day/ animal 1/	Tons/ year 2/
	(1)	(2)	(3)	(4)	(5)
Sows	1	253	40	8.9	45.0
Sows and litters	4	56	20	33.0	73.9
Growing pigs	4	56	162	4.2	76.2
Average finishing pigs	4	53	162	11.4	195.7
Total	--	--	--	--	390.8

-- = Not applicable.
1/ From appendix table 1.

2/ $(5) = \frac{(1) \times (2) \times (3) \times (4)}{2,000}$.

in appendix table 1, and (3) ends up with the annual manure production. The farmer can then determine storage and handling requirements.

The existing system and management alternatives the farmer considers are the following.

Existing system: Daily collection and spreading of manure every 4-6 days.

Option 1: Store for 6 months, scrape lots twice a year, field spreading, and incorporation.

Option 2: Option 1 plus a ditch embankment around the drylot, solids settling basin, and a grass infiltration area.

Option 1 represents changes made to comply with the ban on frozen ground application of manure. This option provides 6-months manure storage and a regular twice-a-year scraping and cleaning of the drylot. Option 2 includes not only these features, but also a ditch embankment around the drylot to control runoff, a solids settling basin, and a grass infiltration area for backup support in case of overflow. In both options, soil incorporation after spreading is planned.

The first step the hog farmer must take after determining the alternative options is to compare the costs and benefits associated with each. The farmer will also want to consider the impact of the various options on existing farm practices and the labor and capital resources available.

Besides the obvious costs associated with new structures and equipment, additional costs will result from peak-time labor demands and crop timing. Labor normally used for handling manure during periods of less critical demand, as in winter, will have to be shifted to more critical labor-demand times, as in spring. Other problems will arise. Equipment used in both manure handling and crop production (for example, tractors) will complicate the management task. And, if soil preparation and crop planting are delayed, reduced yields and lost income could result.

The farmer will realize several primary benefits associated with the new waste management systems. The penalties associated with not meeting guidelines, such as fines or court costs, will be avoided. More of the nutrients in the manure can be saved for crop activities, thus reducing fertilizer costs. Furthermore, manure increases the water-holding capacity of the soil and enhances the soil structure. Better barnyard odor control is possible, particularly at the time of spreading, if timely soil incorporation occurs.

Costs of Manure Management Options

The three management options require no new equipment, as the farmer is assumed to already have a 50-hp diesel tractor, a 16-cubic-foot bucket loader, and a 220-cubic-foot spreader. New facilities and structures include a paved, manure storage area capable of holding a 6-months supply; a diversion terrace to hold and drain liquids, rain, and snow runoff; and an earthen settling basin with a grass infiltration area to filter runoff before it goes into streams or lakes.

The hog operator needs to estimate the costs of labor, equipment, and facilities associated with each option. As the tractors needed are already used for other cropping and livestock enterprises, only the costs of the bucket loader and spreader are included with the variable costs for each option. The costs of special manure facilities, such as terraces and storage, need to be evaluated carefully because these imply additional costs for some, but not all, of the options considered. Table 11 compares the costs of the two options with that for the existing system.

Under the existing waste management method, the spreader is loaded daily and operated when full, usually every 5 days. Approximately 390 tons of manure are produced annually

Table 11--Partial budget analysis of waste management options, 650-head hog operation, Corn Belt

Item	Existing system	Option 1 2/	Option 2 2/
		Dollars	
Additional capital outlays: 1/			
40 x 40 x 6 in. concrete slab	--	3,100	3,100
Diversion terraces (500 ft.)	--	--	150
Earthen settling basin (4,000 ft.) 2/	--	--	880
Seed infiltration area (2,200 ft.) 2/	--	--	180
72-in. bucket loader	2,000	2,000	2,000
220-cu. ft. spreader	3,200	3,200	3,200
Scraper (6-ft. blade)	500	500	500
Subtotal	5,700	8,800	10,010
Less salvage value	1,245	2,795	3,360
Fixed investment to be amortized at 12 percent for 7 years	4,455	6,005	6,650
Annual ownership costs:			
Fixed investment x amortization factor (0.2191)	976	1,315	1,457
Annual operating costs:			
Labor at $3.50/hr.	3/640	4/682	5/704
Fuel and lubricants	99	105	108
Repair and maintenance	25	27	28
Total annual operating costs	764	814	840
Total annual costs	1,740	2,129	2,297
Value of nutrients in manure	1,488	1,727	1,727
Net change in annual costs	+252	+404	+570

-- = Not applicable.

1/ The farm has a 50-hp diesel tractor, 72-in. bucket loader, and a 220-cu. ft. spreader that will be used in all options.

2/ Existing system = daily collection and spreading of manure; option 1 = 6-months storage, twice-a-year scraping of drylot, field spreading and incorporation; and option 2 = option 1 plus ditch embankment around drylot, solids settling basin, and grass infiltration area.

3/ Assumes 165 hrs. for manure collection and 18 hrs. for spreading.

4/ Assumes 165 hrs. for manure collection, 8 hrs. for loading to spreader, 18 hrs. for spreading, and an additional 4 hrs. for lot cleaning (totalling 195 hrs.).

5/ Same labor as option 1, with an additional 6 hrs. for cleaning and spreading from settling basin (totalling 201 hrs.).

(table 10). Assuming 33 cubic feet per ton, about 13,000 cubic feet of waste must be handled annually. Extrapolating from appendix table 7 and assuming a 1,500-foot travel distance, one can estimate that fuel requirements for the existing system will be 86 gallons. Repair and maintenance costs are $25 per year. Fuel and maintenance costs for options 1 and 2 are increased in proportion to the additional time requirements. Approximately 72 loads are spread annually, averaging 15 minutes per load, for a total of 18 hours.

Option 1 meets the new environmental regulations; 6-months manure storage is built so that winter spreading is not necessary. The collection cost of option 1 is identical to the existing system, except that instead of manure being loaded directly into the spreader, it is dumped into the storage area. In the spring and fall, manure is taken out of storage and spread on the land. Loading from storage requires 7 minutes per load; travel and spreading take another 15 minutes. Approximately 26 hours are required each year to load (8 hours) and spread (18 hours) the manure. In addition, manure is scraped from the drylot and is loaded directly on the spreader every 6 months. Approximately 14 tons of solids are loaded and spread each year, requiring an additional 4 hours.

Option 2 is similar to option 1, except that it includes an earthen terrace, a solids settling basin, and an infiltration area. Variable costs are increased slightly to account for cleaning and spreading of the manure from the settling basin.

Estimating Nutrient Value of Manure

Nutrients are the principle tangible benefit when hog manure is recycled through crops. These nutrients come from undigested feed consumed by the animal. The amounts excreted by the animal vary with feed intake and digestion. The amount of remaining nutrients usable in crop production depends on how the manure is collected, stored, and distributed on the land. Nitrogen is the most volatile of the plant nutrients, with most estimates showing a 50-percent loss as ammonia gas. Phosphorus and potash are much more stable, both during handling and after application.

When these normally beneficial plant nutrients are mismanaged, they become sources of potential water pollution. This is especially true with nitrogen. Proper handling and application rates are discussed extensively in a USDA user manual entitled Animal Waste Utilization on Crop and Pasture Land: A Manual for Evaluating Agronomic and Environmental Aspects. The farm manager should be aware of both the benefits and the potential hazards of livestock and poultry manure.

The 390 tons of wet manure produced annually on the 650-head hog farm contain approximately 2.7 tons of nitrogen, 2.0 tons of P_2O_5, and 2.1 tons of K_2O (table 12). The way the manure is handled influences the amount of nutrients saved and made available for crop production, especially nitrogen. Table 13 shows estimates of the available plant nutrients for the three manure handling options. Less nitrogen is lost with options 1 and 2. The values assume 100 percent of the nutrients incorporated into soil would be available to the plant. Nutrients are slow to break down to plant availability. Consequently, several years of cropping may be required to obtain full benefits from the manure. However, if manure is added year after year, the nutrients available to the plant will eventually be about the same as the amounts applied.

Estimating Costs and Benefits

Total annual costs of the three options range from $1,740 for the existing system to $2,297 for option 2. Cost differentials reflect the fact that options 1 and 2 require progressively greater investment and have higher operating costs. The existing system costs less principally because the required capital outlay is only 57-65 percent as great as that for options 1 and 2. The value of the nutrients saved with options 1 and 2

Table 12--Nutrient production estimates, 650-head hog operation, Corn Belt

Animal type	Annual manure production	Total nutrient content 1/		
		Nitrogen	Phosphorus	Potash
	Wet tons	Tons		
Gestating sows	45.0	0.31	0.24	0.24
Sows and litters	73.9	.52	.39	.40
Growing pigs	76.2	.53	.42	.44
Finishing hogs	195.7	1.36	1.01	1.06
Total	390.8	2.72	2.06	2.14

1/ Calculated from data in appendix table 1. The following formula is used:

$$\text{Tons of nutrient} = \text{tons of wet manure} \times \frac{\text{daily nutrient content (lbs.)}}{\text{daily manure production (lbs.)}}$$

Table 13--Nutrients in manure for a Corn Belt 650-head hog operation, by waste management option

Nutrient	Total production	Nutrients available 1/		
		Existing	Option 1 2/	Option 2 3/
		Pounds		
Nutrients in manure:				
Nitrogen (N)	5,440	2,720	4,352	4,352
Phosphorus (P_2O_5)	4,120	3,708	3,708	3,708
Potash (K_2O)	4,280	3,852	3,638	3,638
		Dollars		
Equivalent value of commercial nutrients 4/	--	1,488	1,727	1,727

-- = Not applicable.

1/ Under the existing system, all manure from the farrowing house and the growing house is returned to the land. Manure is spread year round and is not incorporated. Assumes a nutrient loss of 50 percent for nitrogen, 10 percent for phosphorus, and 10 percent for potash (app. table 2).

2/ All manure from the farrowing house and growing house is returned to the land from storage; 14 tons of manure are returned from the drylot. All manure is incorporated after application. Assumes a nutrient loss of 20 percent for nitrogen, 10 percent for phosphorus, and 15 percent for potash (app. table 2).

3/ Includes all the manure in option 1 plus 3,900 pounds collected from the settling basin. Assumes a nutrient loss of 20 percent for nitrogen, 10 percent for phosphorus, and 15 percent for potash (app. table 2).

4/ Value is based on 16 cents/pound for nitrogen, 18 cents/pound for phosphorus, and 10 cents/pound for potash.

is 16 percent greater than for the existing system, but not enough to offset the increased costs.

Several other nonmonetary costs and benefits have not been directly accounted for, but they should be considered by both the hog farmer and the environmental planner. Among these are the following:

1. Loss of yield because of late planting due to twice-a-year manure spreading that may conflict with planting schedules (A rule of thumb used by Corn Belt farmers is a loss of a bushel of yield per acre for each day planting is delayed after May 1.);

2. Loss of management flexibility due to increased proportion of capital investment in hog manure handling equipment and facilities;

3. Decrease of odor from hog manure because of better storage and handling methods; and

4. Decreased potential of stream and lake water pollution from livestock manure runoff.

CORN BELT OPERATION FOR TOTALLY CONFINED HOGS

Although relatively small-volume producers still dominate the U.S. hog industry, it is rapidly moving toward substantially larger hog enterprises. For the 15 leading hog producing States in the 1964-74 period, the share of hog sales from farms selling 1,000 or more head per year increased from 8 to 24 percent. The percentage of hog sales from farms selling less than 100 hogs annually decreased from 21 percent to less than 10 percent. The trend to larger operations has been accompanied by a shift to specialized production systems which present unique waste management problems. Our example focuses on the manure management alternatives for hogs produced under total confinement, when a three-phase production system is used for farrowing, nursing, and finishing. Environmental regulations prohibit winter spreading of manure on frozen land.

The operation is designed to produce about 1,600 head of hogs and pigs per year. There are 11 farrowing cycles per year, each lasting approximately 30 days. Manure is handled as a liquid, which is amenable to a variety of storage facilities and field distribution methods.

The farrowing house is designed for 19 farrowing crates and a stall for washing sows, all having partially slotted floors with alley drains to the pits below the house. The two liquid manure pits below the house are each 3 feet deep, 4 feet wide, and 50 feet long, with a total maximum storage capacity of

1,200 cubic feet. Assuming a management decision that pits will start with 6 inches of liquid in the bottom and will be emptied before the liquid is 1 foot from the top, the actual capacity is reduced to 600-cubic feet which are available for liquid manure collection and storage. Given 7.5 gallons to the cubic foot, there is a maximum safe storage capacity of 4,500 gallons, or 43 days accumulation of wastes, which is more than adequate if the farrowing house pits are cleaned monthly.

The nursery houses 280 pigs at one time and generates about 100 gallons of waste per day. The nursery pens are over fully slotted floors. The pens are designed to hold 20-25 pigs with 3-4 square feet per pig. A 4-foot pit below the nursery provides adequate liquid manure storage capacity up to 210 days. The nursery house is designed to house the young pigs from 3-4 weeks up to 12 weeks of age, at which time they should weigh 75-80 pounds.

The growing-finishing house is designed to accommodate approximately 400 hogs, with 20 hogs per pen and 5-8 square feet per hog. Hogs are kept in the growing-finishing house about 70 days until they reach the 220-230 pound market weight. Animals in the pens produce about 500 gallons of liquid waste daily. The pens are built over partially slotted floors with pits 5 feet deep that will safely hold 30,000 gallons of wastes, or approximately 70-days production.

A fourth house is required for gestating sows and gilts. Each sow in confinement requires 15-20 square feet of building area. The 100 gestating sows and gilts in the house are grouped 10 to a pen on partially slotted floors and fed in a separate part of the building equipped with feeding stalls. Daily waste production for the 100 sows is about 110 gallons of manure and liquids. The pit has capacity for 100-days accumulation.

The annual waste production from this operation, for all production phases, is estimated at approximately 38,700 cubic feet, or about 290,000 gallons (table 14). These volume estimates will be used later in our analysis to estimate storage requirements and nutrient content of the wastes.

Our analysis considers the following options for storage and field distribution:

1. Slotted floors with storage pits
   Above ground storage tanks
   Tank wagon injection to fields

Table 14--Annual waste production, 1,600 head confinement hog operation, Corn Belt

Production phase	Cycles per year	Days per cycle	Animals in each cycle	Waste production: Daily per head 1/	Waste production: Total annual
	-------- Number --------			-- Cubic feet --	
Gestating sows	1	309	100	0.15	4,635
Sows and litters	11	30	19	.54	3,386
Nursery	11	56	152	.04	3,745
Growing-finishing	11	70	152	.19	22,234
Washing and cleaning water 2/	--	--	--	--	4,686
Total	--	--	--	--	38,686

-- = Not applicable.
1/ See appendix table 1.
2/ For farrowing house and nursery, 426 cubic feet for each cycle.

2. Slotted floors with storage pits
   Below ground storage tanks
   Tank wagon application, plow down

3. Slotted floors with storage pits
   Lagoon storage
   Tank wagon injection to fields

4. Slotted floors with storage pits
   Lagoon storage
   Irrigation to fields

One must first estimate storage requirements. In most of the Corn Belt, 6-months storage will be adequate if all building pits and storage facilities are emptied in the fall and the manure is spread prior to the time the ground freezes. However, to provide a safety margin, thus preventing management problems that might result from inadequate storage, we used a minimum of 8-months storage in our analysis. Individual operators must determine their own storage needs according to climate, geography, labor availability, capital outlay, and competition from

other farm enterprises during critical peak periods, such as spring planting and fall harvesting.

Using the factors in appendix table 1, one can calculate daily manure production from each facility. For example, a sow and litter in the farrowing house typically produce 0.54 cubic foot (4.0 gallons) of liquid waste daily. If 19 sows and litters are in the house, 10.2 cubic feet (76 gallons) of liquid manure are produced each day. Over the 30-day period, this accumulates about 2,300 gallons. An additional 1,600 gallons of water are needed to sanitize the farrowing house and clean the sows prior to farrowing, bringing the total liquid manure production from the farrowing house to 3,900 gallons per month.

Table 15 summarizes the existing manure storage capacity and additional requirements. To provide 8-months storage, total storage capacity must be increased by 129 percent, or by about 18,000 cubic feet. The greatest increase is needed for the growing and finishing facilities, followed by the farrowing house and the sow house.

Although several liquid-manure storage options exist, our analysis considers only those mentioned previously. The above-ground storage facility (option 1) can be constructed from several types of building materials. The storage facility used in our example is a commercially produced, treated steel tank or silo. Option 2, below-ground storage, requires a reinforced concrete tank. Storage for options 3 and 4 requires a simple earthen lagoon. Unlike storage in the tanks assumed by options 1 and 2, manure will decompose more quickly in the lagoon, decreasing its quantity and value as a fertilizer.

Manure spreading alternatives include a tank wagon with injection, a tank wagon without injection, and irrigation. The latter two alternatives assume soil incorporation within 7 days of application.

Transferring Manure from Pits to Storage

In all options, manure is transferred from the pits below the houses to a storage structure. A high-pressure pump is used for transfer. The pump requires an 80 PTO horsepower tractor for power, which uses about 5 gallons of diesel per hour. Pumping at 500 gallons per minute would require slightly more than 7 hours annually to empty all the manure from the pits to storage. Although all the manure need not be transferred from the pits to storage before field spreading, our analysis assumes all manure will go to storage and then to the field.

Manure Storage

From table 15 we estimated that approximately 18,000 cubic feet of additional storage are required to provide 8-months of storage. All four options meet this requirement. We selected

Table 15--Manure production and storage capacity, 1,600-head confined hog operation, Corn Belt

Type of house	Capacity	Capacity needed for 8 months			Existing storage		Additional capacity needed
		Manure 1/	Water 2/	Total	Total capacity of pits 3/	Safe storage capacity 4/	
	Head	Cubic feet					
Farrowing	19 sows and litters	2,260	1,700	3,960	1,200 (3 ft.)	600	3,360
Nursery	280	2,509	1,700	4,209	4,480 (4 ft.)	2,800	1,409
Growing-finishing	400	15,900	--	15,900	5,720 (5 ft.)	4,004	11,896
Sow-gilt	100	3,100	--	3,100	2,400 (3 ft.)	1,200	1,200
Total	--	23,769	3,400	27,169	13,800	--	17,865

-- = Not applicable.

1/ Calculated by multiplying annual waste production in table 14 by 0.67.

2/ Assumes that 3,200 gallons of water are used per month for sanitizing, cleaning, and flushing in farrowing and nursery houses.

3/ Number in parentheses is pit depth.

4/ Safe storage will be somewhat less than total capacity. Safe storage assumes 6 inches of water at bottom of pit at start and that pits are emptied when filled to 1 foot below capacity. One can calculate additional storage requirements by adjusting existing total capacity by a safe storage factor and subtracting this figure from the 8-month capacity requirements. The safety adjustment factor is 0.625 for the nursery, 0.7 for the growing-finishing house, and 0.5 for the farrowing and gilt house. Thus, the additional capacity for the farrowing house is 3,960 - (1,200)(0.5) = 3,360.

different storage facilities to illustrate structures that may be necessary because of soil, terrain, or space requirements that exist in different geographical regions.

The steel tank or silo is a commercially produced, above-ground storage structure (option 1). Among its advertised advantages are the following: it takes less valuable space than a lagoon; it has high sides to help check odors and to protect children and livestock, thereby eliminating the need for expensive fencing; and it provides positive containment, preventing leakage. The complete structure, including valves and concrete pad, costs approximately $20,000. Little or no maintenance is required.

Option 2 uses a below-ground concrete tank. The estimated cost of this structure is $6,300, including excavation at $1 per cubic yard and concrete and reinforcement bars at $1 per square foot. The tank has a 6-inch concrete base and 6-inch walls; it is 60 feet long, 45 feet wide, and 10 feet deep. Costs do include fencing for safety, but no tank cover. Variable costs are near zero.

Options 3 and 4 use a storage lagoon, which acts as a small-scale, waste treatment plant, providing aerobic digestion. Lagoons properly designed and managed offer some of the following advantages: low costs for the volume of storage, continuous biological decomposition and settling out of manure solids, and relatively odor-free manure when spread. However, there can be a number of disadvantages, including the possibility of objectionable odors in the spring, especially if the lagoon turns anaerobic; excessive buildup of sludge; and ground or surface water pollution, if the lagoon is improperly constructed or managed. Also, a significant loss (80 percent) of nitrogen occurs, compared with the above-ground storage tanks.

We consider two lagoon sizes in our analysis. Selection is based on the method of emptying--irrigation or spreader tank. Emptying through irrigation may require dilution of the slurry to a 95-percent solution to prevent irrigation equipment problems. Typically, this process requires adding water equal in volume to the stored liquid manure. However, this additional water is generally added to keep the lagoon in an aerobic condition prior to irrigation. In addition to the storage and dilution volumes, aerobic lagoons require a minimum volume to insure a bacteria population adequate for continuous waste decomposition. The lagoon type we selected is single cell with twice-a-year dewatering. We estimated the required lagoon sizes, using the factors in appendix table 6 and estimates of live animal weight. The average annual estimate of live animal weight assumes an average herd size of 800 head at 150 pounds

per head (120,000 pounds). Thus, the minimum lagoon size for dewatering by irrigation is 210,000 cubic feet (120,000 x 1.75) and for dewatering by tank truck is 186,000 cubic feet (120,000 x 1.55). At $1 per cubic yard, the excavation costs for the two lagoons are approximately $7,800 and $6,900, respectively.

Moving Manure from Storage to Field

The two basic methods available for field application of liquid manure are the spreader tank (with or without injectors) and irrigation. Options 1 and 2 use the spreader tank, whereas options 3 and 4 incorporate both the spreader tank and a traveling gun irrigation system.

Spreader tanks can vary from 750 to 4,500 gallons. We used a 3,000-gallon (400-cubic foot) spreader tank in this example, with an initial cost of $8,200--$7,000 for the tank wagon and $1,200 for two injectors. Although horsepower requirements will vary with terrain and soil conditions, the suggested minimum tractor size for the 3,000-gallon tank is 75 hp without injectors. A 100-hp tractor is needed for the 2-injector tank wagon, as an additional 12 hp are needed per injector.

If the distance to the application area from the storage site is known, the total travel, spreading, and loading times can be figured from appendix table 9. This example assumes a 1,500-foot travel distance with the spreader tank 90 percent full (360 cubic feet). Consequently, 76 loads are needed to apply 27,200 cubic feet, requiring 27 hours of labor. Approximately 1,000 cubic feet can be spread per hour; 7 hours of pump time are required to load the tanks. The annual fixed costs of the tractor are not included as they are incurred primarily in cropping activities.

The cost of a new, traveling gun irrigation system, including 1,500 feet of 8-inch pipe, is approximately $15,750. This system is capable of handling 500 gallons of manure per minute, using the same high-pressure pump needed to transfer the manure from pits to storage area. At 500 gallons per minute, about 7 hours are required to dewater the 8-month storage lagoon, or 10 hours per year. The variable costs associated with operation include the energy cost of the tractor needed to power the high-pressure pump, plus labor, and the energy requirements of the irrigation system. These costs could be substantially reduced if the irrigation system was a regular part of crop production and was not used exclusively for spreading liquid manure.

Returns from Hog Manure

Plant nutrients in hog manure are determined largely by the feed consumed by the animal. Estimates of the nutrient value of manure depend on total production, losses associated with

handling, and prices for each nutrient. Table 16 presents estimates of nutrients produced by the hogs in this system. Table 17 presents the amounts and values of nutrients available for each of the four waste management options. Nutrients available to plants in the first year after initial application represent 60 percent of the nitrogen, 75 percent of the phosphorus, and 80 percent of the potash. After a few years of regular manure applications, the amount of available nutrients to plants essentially equals the total nutrient application rate.

Summary of Costs and Returns

Table 18 summarizes cost data for these four options. Certain costs are common to all options, such as that for the pump needed to move the manure from the collection pits to the storage tanks and that for the spreader tank with injections required by options 1, 2, and 3. One would normally consider only those costs unique to the various alternatives. For example, transferring the liquid manure from the pits below the hog houses to one of the storage alternatives is common to all options and would thus be omitted. However, in this example, we are also interested in computing all the costs associated with the environmental regulation which precludes winter spreading. Consequently, our analysis considers all costs beyond manure collection so that we can estimate the total cost of each option in the example.

Storage for options 1 and 2 is in tanks--above ground for option 1 and below ground for option 2. Options 3 and 4 use lagoons for storage. Option 4 requires a large lagoon as additional water must be added to the wastes for successful irrigation. The costs of the storage structures are significant factors. Here, the largest increase in annual costs is with option 4, followed by option 3. The lowest cost increase is with option 2, due to its relatively lower investment requirements and higher nutrient savings benefit. The total cost of irrigation equipment in option 4 is charged to waste management. If the equipment were also used for regular crop irrigation, some of the capital costs could be spread out, thus reducing the direct cost of the waste management system. The largest capital investment is required in option 1, primarily because of the treated steel tank. However, much of this cost is offset by the increased value of plant nutrients in the manure.

The value of nutrients returned to the fields can be used to offset the manure management costs. The process for estimating these values is based on assumptions of manure production per head of livestock, nutrient content of these wastes, losses of nutrients with different waste handling systems, and prices assumed for the nutrients. As indicated in table 18, options 1

Table 16--Nutrient production, 1,600-head confinement hog operation, Corn Belt

Production phase 1/	Cycles per year	Days per cycle	Animals in each cycle	Daily nutrient production 2/			Total annual production		
				Nitrogen	P_2O_5	K_2O	Nitrogen	P_2O_5	K_2O
	Number			Pounds/head			Pounds		
Gestating sows	1	309	100	0.062	0.048	0.048	1,915	1,483	1,483
Sows and litters	11	30	19	.230	.173	.181	1,442	1,084	1,135
Nursery	11	56	152	.016	.012	.012	1,498	1,124	1,124
Growing-finishing	11	70	152	.079	.059	.062	9,246	6,905	7,256
Total	--	--	--	--	--	--	14,101	10,596	10,998

-- = Not applicable.

1/ Assumes 19 sows farrowing four times per year; nursery with a capacity of 280 pigs and feeder capacity of 400 head; and 100 sows and gilts on hand.

2/ From appendix table 1.

Table 17--Nutrients in manure for a Corn Belt 1,600-head confined hog operation, by waste management option

Nutrient	Options 1 and 2	Options 3 and 4
	Pounds/year	
Total production: 1/		
Nitrogen	14,100	14,100
Phosphorus	10,600	10,600
Potash	11,000	11,000
Nutrients available for plants per year: 2/		
Nitrogen	5,900	1,300
Phosphorus	7,600	4,000
Potash	8,400	5,300
	Dollars	
Nutrient value 3/	3,152	1,458

1/ From table 16.

2/ Nutrients available after losses through handling, storing, and spreading. The losses of nitrogen, phosphorus, and potash for options 1 and 2 are 30 percent, 5 percent, and 5 percent, respectively; those for options 3 and 4 are 85 percent, 50 percent, and 40 percent, respectively (app. table 2). About 60 percent of nitrogen, 75 percent of phosphorus, and 80 percent of potash applied on the field is available for plant use each year.

3/ Nutrients were valued at 16 cents for nitrogen, 18 cents for phosphorus, and 10 cents for potash. Nutrients are valued as plant-available during the growing season. The values of minor elements, such as calcium and manganese, are omitted from this analysis.

Table 18--Partial budget analysis of waste management options, 1,600-head confined hog operation, Corn Belt 1/

Item	Option 1	Option 2	Option 3	Option 4
		Dollars		
Additional capital outlays:				
High-pressure pump with 100-ft. extra hose and couplings	3,500	3,500	3,500	3,500
Treated steel tank 2/	20,000	--	--	--
Reinforced concrete tank 3/		6,300		
Earthen lagoon 4/			6,900	7,800
Spreader tank with injectors 5/	8,200	8,200	8,200	
Traveling gun irrigation system with 1,500 ft. of 8-in. pipe				15,750
Subtotal	31,700	18,000	18,600	27,050
Less salvage value	11,170	4,320	4,620	6,570
Fixed investment to be amortized at 12 percent for 7 years	20,530	13,680	13,980	20,480
Annual ownership costs:				
Fixed investment x amortization factor (0.2191)	4,498	2,998	3,063	4,487
Annual operating costs:				
Labor at $3.50/hr.	6/96	6/96	6/96	52
Fuel costs:				
Pumping to storage 7/	65	65	65	65
Hauling to field 8/	240	240	240	--
Pumping to field 9/				60
Repair and maintenance 10/	69	69	69	50
Subtotal	470	470	470	227
Total annual costs	4,968	3,468	3,533	4,714
Return from manure as plant nutrients	3,152	3,152	1,458	1,458
Net increase in annual costs	1,816	316	2,075	3,256

-- = Not applicable.

1/ Option 1 = above-ground storage tank with tank wagon injection; option 2 = below-ground storage tank and tank wagon injection; option 3 = lagoon storage and tank wagon injection; and option 4 = lagoon storage and irrigation.

2/ Assumes 200,000-gal. capacity.

3/ 60 ft. x 45 ft. x 10 ft. = 202,500-gal. capacity.

4/ Lagoon size was estimated from appendix table 6 and from estimates of average annual weight of liveweight hogs. A one-stage lagoon with twice-a-year dewatering was used. Option 4 requires a larger lagoon because dilution water is added. Excavation is assumed to cost $1/cu. yd. Required volumes are: 120,000 x 1.55/27 = 6,889; 120,000 x 1.75/27 = 7,778 cu. yds. with irrigation.

5/ Assumes 3,000-gal. capacity.

6/ Based on appendix table 9.

7/ Based on 5 gal./hr.; 7 hrs.; $1/gal.; 15 percent for lubrication; adjustment factor for tractor.

8/ Based on appendix table 7.

9/ Assumes 50 gal. of fuel plus miscellaneous.

10/ Based on appendix table 8 for spreading equipment; assumption for option 4.

and 2 each return $3,152 in nutrient value, whereas options 3 and 4 each return $1,458. The value of remaining nutrients with options 3 and 4 is reduced by nitrogen volatilization losses in the lagoon treatment process.

Environmental Considerations

Adding additional storage capacity to the existing pits under hog houses will reduce the potential for environmental damage. The potential of nutrient runoff from animal waste is greatest when manure is spread on sloping frozen ground. Nutrients can also escape to lakes and streams if manure is applied in greater concentrations than those that can be absorbed and used by a crop during its growing season. The manual, Animal Waste Utilization on Cropland and Pastureland, prepared by USDA, provides information on land application rates that will increase soil fertility and crop yields. Following the recommendations and guidelines in the manual should help the farmer avoid excessive or improper application of manure that might endanger the environment.

Odor is yet another environmental concern in our society. Nuisance complaints and litigation against producers are frequently due to odors rather than to water pollution. The management options considered in our analysis vary in the degree of odor control. The storage tanks provide nearly equal odor protection. During a 2-week period in the spring, the lagoon may emit offensive gases caused by heavy bacterial action as the liquid warms up. In terms of both odor and water pollution, the injector tank wagon is superior to either the surface-spread wagon or irrigation because the manure is incorporated in the soil rather than deposited on the surface.

CORN BELT FARMER-FEEDER OPERATION

In this example, we consider some adjustments that a management decision to expand might present to a farmer-feeder operation in the Corn Belt. In addition to expansion costs, the farmer must meet environmental regulations. Expansion costs and runoff controls must be analyzed for their effect on the profitability of the feedlot.

A feedlot operator currently buys 500-pound feeder steers and feeds them until they weigh about 1,100 pounds. The steers usually spend about 7 months in the lot. The feedlot is soil surfaced, protected by a windbreak, and has a one-time capacity of 150 head. Manure builds up on the lot and is spread on cropland in the spring and fall. Currently, the lot has no waste control or runoff facilities.

The feedlot operator is considering expanding the lot to a one-time capacity of 500 head. However, the State's stream pollution control board, which regulates confined animal feeding operations, has required that plans and specifications for

waste treatment and runoff control facilities be submitted before a discharge permit will be issued. The cattle feeder, with the help of the county extension agent and SCS, prepares plans that include paving the feedlot and channeling all feedlot runoff through a solids settling basin to a holding pond. The plan also provides for draining precipitation not falling on the lot away from the feedlot and holding ponds and for constructing a shelter at one end of the feedlot.

Option 1

The first option is for the farmer to increase capacity by paving the existing drylot. In the Corn Belt, each animal needs about 250 square feet in dirt lots and about 70 square feet on paved lots. Thus, expansion to 500 head can be accomplished by paving the existing lot. Paving and curbing the existing lot, which covers about 38,000 square feet, will cost an estimated $22,800, assuming a paving cost of 60 cents/square foot.

Shelter is desirable because, during bad weather, it provides comfort to the animals, leading to increased productivity. Shelter also reduces runoff and potential water pollution from the lot by reducing the area exposed to precipitation. The shelter will be enclosed on three sides and constructed at one end of the lot. The recommended shelter size in the Corn Belt is 20 square feet per animal, plus space for feed bunk and water tanks. Consequently, this shelter would need to be 10,000 square feet. Based on construction costs of $2.50/square foot, the structure would cost $25,000.

Before determining the size and construction cost of the runoff control structures, the operator must first estimate runoff. The quantity of runoff depends on the size of the feedlot, the annual precipitation, the soil type, and slope. Runoff per square foot from paved lots is estimated at 80 percent of precipitation, whereas on dirt lots it is estimated at 30 percent. Average annual precipitation for the area is 36 inches. The exposed area in this feedlot is 28,000 (38,000 - 10,000) square feet. Total annual runoff from this paved feedlot is estimated at 502,400 gallons, or 67,200 cubic feet (28,000 square feet x 36/12 inches x 0.8).

The plans the feedlot operator prepares specify that the holding pond be capable of storing one-third of the average annual runoff. Consequently, about 22,200 cubic feet are needed. Construction costs of the holding pond will be about $822, assuming an excavation cost of $1 per yard.

A variety of settling basin designs have been developed, but in our example, the lot is paved and curbed. Runoff from the lot is collected at one end by gravity. The runoff flows into a settling basin, which is 10 feet wide, 5 feet deep, and 200 feet

long. A standpipe drains the basin to the holding pond by gravity. Excavation and culvert pipe for constructing the settling basin cost $500 ($370 + $130).

Table 19 summarizes construction costs for expanding the feedlot capacity to 500 head and for adding runoff control facilities. The total investment cost would be $49,122 with an annual ownership cost of $7,210, or about $14.50 per animal, assuming 500 head are finished each year.

The feedlot operator must now decide if the expansion requiring an investment of nearly $50,000 would be profitable. First, the farmer must decide whether the business will continue long enough to justify such an expenditure. Second, the farmer must evaluate whether future environmental regulations will force additional adjustments. Future complaints, for example, might focus on odor problems in addition to water pollution.

Rather than expand, the farmer may decide to continue raising the same number of livestock at the same location and to develop runoff control measures from the existing situation. Alternatively, the farmer could move the feedlot to a different site on the same farm or to another farm where improvements may not be so prohibitive.

Option 2

Let us suppose the manager of the above feedlot concludes that the plan to pave the feedlots is too costly. Instead of choosing a paved lot with shelter, the manager decides to explore expanding the existing soil-surfaced lot. Space is not a limiting problem. About 4 acres of pasture would be removed to expand the feedlot and build runoff control structures.

The area of the alternative unpaved feedlot would have to be expanded from 38,000 to about 125,000 square feet to comfortably accommodate 500 animals. This requires about 1,100 linear feet of new fence and 150 feet of new windbreak fence. Feedlot fence can be built for $1.10/linear foot, whereas the windbreak fencing costs $1.60/linear foot. Total investment cost for fencing the large feedlot would be $1,450, with an annual fixed cost of $346 per year.

The settling basin and storage pond must be larger to account for the greater runoff area in the larger lot. However, this requirement is partly offset by the smaller volume of runoff per square foot from dirt lots, as runoff on soil-surfaced lots is 30 percent of precipitation, whereas on paved lots, runoff is 80 percent. Total runoff in gallons can again be estimated by the equation (125,000 square feet x 36/12 inches x 0.3), which is equal to 112,500 cubic feet or 841,050 gallons.

Table 19--Partial budget analysis of waste management options, Corn Belt feeder expansion

Item	Option 1 1/	Option 2 2/ 3/
	Dollars	
Additional capital outlays:		
Pave feedlot	22,800	--
Shelter construction	25,000	--
Settling basin	500	588
Holding pond	822	1,390
Build new fence	--	1,450
Subtotal	49,122	3,428
Less salvage value (33 percent)	16,210	1,131
Fixed investment to amortize at 12 percent for 7 years	32,911	2,397
Annual ownership costs (fixed investment x amortization factor (0.2191)	7,210	525

--Not applicable.

1/ Pave existing lot, construct shelter, settling basin, and holding pond.

2/ Expand dirt lot, expand fences, construct settling basin and holding pond.

3/ An important annual cost omitted is the value of production of the farm acres of pasture taken out of production--that is, the opportunity cost of this land in an alternative enterprise.

If the holding pond must be designed to hold one-third of the annual runoff, it would need to hold at least 37,500 cubic feet. If excavation costs are $1/square yard, the holding pond construction will cost about $1,390. Periodic dewatering costs are omitted from this analysis.

The settling basin, designed to hold the runoff from a 4-inch rain, is 250 feet long, 10 feet wide, and 5 feet deep. The cost of excavation is $463. The drainage and standpipe to the holding pond will increase the total investment in the settling basin to $588 (see table 19).

The annual ownership costs of option 2 are considerably less than those for option 1--$525 compared with $7,210. With such an investment differential, the manager's decision is obvious. Both options will meet environmental goals. The cost of the second option is understated by the opportunity cost of the pastureland that would be converted to a feedlot. Even if that cost were $100 an acre, the annual costs of option 2 would still only be about 13 percent of that for option 1. For the costs of the two alternatives to be comparable, an opportunity cost of about $1,670 per acre would have to be assumed for the pastureland ((7,210 - 525) ÷ 4). However, there may be positive impacts on the efficiency of beef production associated with the shelter and paved lots that our analysis neglects. If they were significant, the cost differences between the two options would be less.

In this example, the feedlot manager examined two different options associated with feedlot expansion. The first one called for substantial expenditures for feedlot and runoff control structures. The second option was considerably more modest, but it provided for equal runoff control protection. Many factors influence a manager in assessing alternatives--such as the anticipated length of life of the firm, its capital position, labor availability, and other competing farm enterprises, such as crop and livestock production.

Neither plant benefits from manure nutrients nor have the variable costs associated with cleaning, storing, or manure handling been considered in this example. Instead, our discussion has focused on two investment decisions that a farmer might consider for a given feedlot expansion or for runoff control protection.

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Appendix table 1--Daily manure production and nutrient content, by livestock species, by animal weight

Species	Weight	Daily manure production		Water	Daily nutrient content		
					Nitrogen	P_2O_5	K_2O
	----Pounds----	Cubic feet	Gallons	Percent	---------Pounds----------		
Dairy	150	12.0	0.19	1.5	87.3	0.06	0.03	0.05
do.	250	20.0	.32	2.4	87.3	.10	.05	.08
do.	500	41.0	.66	5.0	87.3	.20	.08	.17
do.	1,000	82.0	1.32	9.9	87.3	.41	.17	.33
do.	1,400	115.0	1.85	13.9	87.3	.57	.23	.46
Beef	500	30.0	.50	3.8	88.4	.17	.13	.15
do.	750	45.0	.75	5.6	88.4	.26	.19	.23
do.	1,000	60.0	1.00	7.5	88.4	.34	.25	.29
do.	1,250	75.0	1.20	9.4	88.4	.43	.32	.37
Swine:								
Nursery pig	35	2.3	.04	.27	90.8	.016	.012	.012
Growing pig	65	4.2	.07	.48	90.8	.029	.023	.024
Finishing pig	150	9.8	.16	1.13	90.8	.068	.050	.054
do.	200	13.0	.22	1.50	90.8	.090	.068	.071
Average finishing pig	175	11.4	.19			.079	.059	.062
Gestating sow	275	8.9	.15	1.10	90.8	.062	.048	.048
Sow and litter	375	33.0	.54	4.00	90.8	.230	.173	.181
Boar	350	11.0	.19	1.40	90.8	.078	.059	.061

Sources: (8, 43, 56, 65). Numbers in parentheses refer to items in the reference section at the end of the text.

Appendix table 2--Estimated nutrient losses, by method of handling, storing, and spreading livestock manure

Method	Nutrient loss		
	Nitrogen	Phosphorus	Potash
	Percent		
Daily cleaning and surface spreading of solid manure, not tilled on day of spreading	50	10	10
Stacking in covered storage with solid spreading, soil incorporated	15	10	10
Stacking in uncovered storage with solid spreading, soil incorporated	20	10	15
Stacking in uncovered storage with solid spreading, surface spread	35	10	15
Manure stored on dirt dry lot, scraped, hauled, and surface spread	65	15	15
Under-the-floor manure pits or storage tanks, liquid spreading, soil incorporated	30	5	5
Under-the-floor manure pits or storage tanks, liquid spreading, surface spread	45	10	10
Paved dry lot with runoff control to holding pond, spread with irrigation	80	40	30
Flush cleaning with liquid manure, drained to lagoon, dewatered by irrigation, or tank spread and injected	85	50	40
Flush cleaning with liquid manure drained to settling basin, and onto lagoon, dewatered by irrigation	90	60	50

Appendix table 3--Nitrogen lost at ground surface as free ammonia, by soil type

Days between application and incorporation	Nitrogen loss		
	Warm dry soil	Warm moist soil	Cool moist soil
	Percent		
1	30	10	0
4	40	20	5
7 or more	50	30	10

Appendix table 4--Estimated nitrogen losses by denitrification from manure, by soil drainage class

Drainage class	Nitrogen loss
	Percent
Excessively drained	0
Well drained	10
Moderately well drained	20
Somewhat poorly drained	30
Poorly drained	40
Very poorly drained	50

Appendix table 5--Density of bedding materials

Material and form	Density
	Pounds/cubic foot 1/
Straw:	
Loose	3.5 - 4.5
Baled	6.0 - 10.0
Chopped	5.7 - 8.0
Shavings:	
Baled	201.0
Loose	8.8
Sawdust	12.0

1/ Estimated from the following formula:

$$\text{lbs. bedding/cu. ft.} = \frac{0.5\ (\text{lbs. bedding used})}{\text{bedding density (lbs./ft.)}}$$

Source: (30, table 9-4).

Appendix table 6--Recommended livestock lagoon volume, by type and function

Livestock and lagoon volume	Once-a-year dewatering			Twice-a-year dewatering		
	One-stage lagoon	Two-stage lagoon		One-stage lagoon	Two-stage lagoon	
		1st cell	2nd cell		1st cell	2nd cell
	Ft.^{3}/lb. of live animal weight					
Swine:						
Design volume	1.35	1.25	0.35	1.35	1.25	0.35
Storage volume	.40	--	.40	.20	--	.20
Dilution volume	.40	--	.40	.20	--	.20
Total volume	2.15	1.25	1.15	1.75	1.25	.75
Beef:						
Design volume	1.50	1.25	.50	1.50	1.25	.50
Storage volume	.34	--	.34	.17	--	.17
Dilution volume	.34	--	.34	.17	--	.17
Total volume	2.18	1.25	1.18	1.84	1.25	.84
Dairy:						
Design volume	1.75	1.50	.50	1.75	1.50	.50
Storage volume	.50	--	.50	.25	--	.25
Dilution volume	.50	--	.50	.25	--	.25
Total volume	2.75	1.50	1.50	2.25	1.50	1.00

-- = Not applicable.
Sources: (43, 56, 65).

Appendix table 7--Estimated gallons of diesel fuel to load, haul, and spread manure from storage to cropland, by spreader size

Spreader size	Travel distance	Thousand cubic feet of manure				
		20	40	60	80	100
	Feet	Gallons 1/				
150 cu. ft.	500	121	242	363	484	605
	1,000	139	278	417	555	694
	1,500	157	314	470	627	784
	2,000	174	349	523	698	872
	2,500	192	383	576	768	960
220 cu. ft.	500	115	230	345	461	576
	1,000	129	257	387	515	643
	1,500	143	286	429	572	715
	2,000	158	315	473	630	787
	2,500	171	341	512	683	854
270 cu. ft.	500	116	231	347	463	574
	1,000	129	258	388	517	646
	1,500	142	284	426	568	710
	2,000	152	304	457	609	761
	2,500	172	344	516	688	860
1,500 gal.	500	154	308	462	616	769
	1,000	178	356	534	712	890
	1,500	202	404	606	808	1,009
	2,000	226	452	678	899	1,130
	2,500	250	500	749	999	1,249
3,000 gal.	500	123	247	370	493	617
	1,000	138	277	415	554	692
	1,500	152	305	457	611	763
	2,000	167	334	501	669	835
	2,500	181	363	544	725	907
4,500 gal.	500	133	267	400	533	666
	1,000	147	294	440	587	733
	1,500	159	318	476	635	794
	2,000	172	343	515	687	859
	2,500	184	368	553	737	921

1/ Straight line interpolation can be used to determine intermediate values.

Appendix table 8--Estimated cost of repair and maintenance for manure loading, hauling, and spreading equipment, by spreader size

Spreader size	Travel distance	Thousand cubic feet of manure				
		20	40	60	80	100
	Feet	Dollars 1/				
150 cu. ft.	500	41	83	124	165	206
	1,000	47	93	140	186	232
	1,500	52	104	156	207	259
	2,000	57	114	171	228	285
	2,500	62	124	186	249	311
220 cu. ft.	500	35	70	105	140	175
	1,000	39	77	115	154	192
	1,500	42	84	126	168	211
	2,000	46	91	137	183	228
	2,500	49	98	147	196	246
270 cu. ft.	500	42	85	127	170	212
	1,000	47	93	140	187	234
	1,500	51	102	153	204	255
	2,000	55	111	166	221	277
	2,500	60	119	179	239	298
1,500 gal.	500	51	102	153	204	255
	1,000	59	117	176	234	293
	1,500	66	133	199	265	332
	2,000	74	148	222	296	370
	2,500	82	163	245	326	408
3,000 gal.	500	41	81	122	162	203
	1,000	45	91	136	181	226
	1,500	50	100	149	200	249
	2,000	54	109	163	217	271
	2,500	59	118	177	236	296
4,500 gal.	500	39	78	117	656	195
	1,000	43	85	128	171	213
	1,500	46	93	139	185	231
	2,000	50	100	150	200	250
	2,500	53	107	161	214	268

1/ Straight line interpolation can be used to determine intermediate values.

Appendix table 9--Time required to load, haul, and spread manure from storage to cropland, by spreader size

Spreader size	Travel distance	Thousand cubic feet of manure				
		20	40	60	80	100
	Feet	Hours 1/				
150 cu. ft.	500	51	102	152	203	254
	1,000	56	113	169	226	282
	1,500	62	124	186	248	310
	2,000	69	137	206	275	343
	2,500	75	149	224	298	373
220 cu. ft.	500	43	87	139	173	217
	1,000	47	94	140	187	234
	1,500	51	102	153	204	255
	2,000	56	112	168	223	279
	2,500	60	119	179	239	299
270 cu. ft.	500	40	81	121	161	202
	1,000	44	88	132	176	220
	1,500	47	94	141	188	235
	2,000	50	101	151	202	252
	2,500	54	109	163	217	271
1,500 gal.	500	25	50	75	100	125
	1,000	29	57	86	114	143
	1,500	32	64	95	127	159
	2,000	36	71	107	143	179
	2,500	39	77	116	154	193
3,000 gal.	500	17	33	50	66	83
	1,000	18	37	55	73	92
	1,500	20	40	60	79	99
	2,000	22	43	65	87	108
	2,500	24	48	71	95	119
4,500 gal.	500	14	27	41	54	68
	1,000	15	30	45	69	74
	1,500	16	32	48	63	79
	2,000	17	34	51	68	85
	2,500	18	37	55	73	92

1/ Straight line interpolation can be used to determine intermediate values.

Appendix table 10--Ownership costs for waste handling equipment, machinery, and facilities, 1978

Item	Description	Initial cost 1/	Salvage value 2/
		Dollars	
1	Piston pump and accessories	8,000	3,100
2	High pressure pump, for unloading pits and lagoons	3,500	350
3	Gutter cleaner	4,000	1,295
4	Mechanical scraper (12-ft. blade)	6,000	2,220
5	Tractor scraper (6-ft. blade)	500	185
6	Frontend loader (72-in. bucket)	2,000	740
7	Stacker elevator, 30 ft.	2,400	240
8	Steer skid loader	10,300	3,811
9	Lagoon or pit agitator pump (1,200 gal./min.)	3,000	300
10	Lagoon or pit agitator pump (3,000 gal./min.)	4,000	400
11	Solid manure spreader (150 cu. ft.)	2,400	240
12	Solid manure spreader (220 cu. ft.)	3,200	320
13	Solid manure spreader (270 cu. ft.)	4,800	480
14	Liquid manure spreader (1,500 gal.)	5,000	500
15	Liquid manure spreader (3,000 gal.)	7,000	700
16	Liquid manure spreader (4,500 gal.)	11,000	1,100
17	Two-shank injector for liquid spreaders	1,200	120
18	Four-shank injector for liquid spreaders	2,000	200
19	Stationary gun irrigator	1,200	444
20	Single-gun traveling cable, winch drive	5,000	2,500
21	Slurry shooter irrigator	10,000	3,700
22	High-pressure, centrifical pump with chopper	5,000	500
23	Flush tanks	1,250	500
24	1,000-ft. 8-in. aluminum mainline pipe	5,000	2,500
25	Treated steel manure tank (140,000 gal.)	16,500	8,250
26	Treated steel manure tank (200,000 gal.)	20,000	10,000
27	Concrete below ground manure tank (60 ft. x 45 ft. x 10 ft.)	6,300	3,150
28	Earthen lagoon (147,250 cu. ft.)	5,500	2,750
29	Earthen lagoon (166,250 cu. ft.)	6,200	3,100
30	Concrete slab (40 ft. x 40 ft. x 6 in.)	3,100	1,550
31	Earth diversion terrace (500 lineal ft.)	150	75
32	Earthen settling basin (4,000 sq. ft.)	880	440
33	Infiltration area (2,200 sq. ft.)	180	90

1/ Estimated new cost of equipment, machinery, or facility in 1978.
2/ Estimated value of equipment, machinery, or facility at the end of 7 years of designed use.

Appendix table 11--Capital amortization table

Year	Interest rate (percent)							
	5	6	7	8	9	10	11	12
	Dollars 1/							
1	1.0500	1.0600	1.0700	1.0800	1.0900	1.1000	1.1100	1.1200
2	.5378	.5454	.5531	.5608	.5685	.5762	.5839	.5917
3	.3672	.3741	.3810	.3880	.3950	.4021	.4092	.4164
4	.2820	.2886	.2952	.3019	.3087	.3155	.3223	.3292
5	.2310	.2374	.2439	.2505	.2571	.2638	.2706	.2774
6	.1970	.2034	.2098	.2163	.2229	.2296	.2364	.2432
7	.1728	.1791	.1856	.1921	.1987	.2054	.2122	.2191
8	.1547	.1610	.1675	.1740	.1807	.1874	.1943	.2013
9	.1407	.1470	.1535	.1601	.1668	.1736	.1806	.1877
10	.1295	.1359	.1424	.1490	.1558	.1628	.1698	.1770
11	.1204	.1268	.1334	.1401	.1470	.1540	.1611	.1684
12	.1128	.1193	.1259	.1327	.1396	.1468	.1540	.1614
13	.1065	.1130	.1196	.1265	.1336	.1408	.1482	.1557
14	.1010	.1076	.1143	.1213	.1284	.1358	.1432	.1509
15	.0963	.1030	.1098	.1168	.1241	.1315	.1391	.1468
16	.0923	.0990	.1059	.1130	.1203	.1278	.1355	.1434
17	.0887	.0954	.1024	.1096	.1170	.1247	.1325	.1405
18	.0856	.0924	.0994	.1067	.1142	.1219	.1298	.1379
19	.0828	.0896	.0968	.1041	.1117	.1196	.1276	.1358
20	.0802	.0872	.0944	.1018	.1096	.1175	.1256	.1339
21	.0780	.0850	.0923	.0998	.1076	.1156	.1238	.1322
22	.0760	.0830	.0904	.0980	.1059	.1140	.1223	.1308
23	.0741	.0813	.0887	.0964	.1044	.1126	.1210	.1296
24	.0725	.0797	.0872	.0950	.1030	.1113	.1198	.1285
25	.0710	.0782	.0858	.0937	.1018	.1102	.1187	.1275
26	.0696	.0769	.0846	.0925	.1007	.1092	.1178	.1266
27	.0683	.0757	.0834	.0914	.0997	.1083	.1164	.1259
28	.0671	.0746	.0824	.0905	.0988	.1074	.1163	.1252
29	.0660	.0736	.0814	.0896	.0981	.1067	.1156	.1247
30	.0650	.0726	.0806	.0888	.0973	.1061	.1150	.1241

See footnote at end of table.

Continued--

Appendix table 11--Capital amortization table--Continued

Year	Interest rate (percent)							
	13	14	15	16	17	18	19	20
	Dollars 1/							
1	1.1300	1.1400	1.1500	1.1600	1.1700	1.1800	1.1900	1.2000
2	.5995	.6073	.6151	.6230	.6308	.6387	.6466	.6546
3	.4235	.4307	.4380	.4453	.4526	.4599	.4673	.4747
4	.3362	.3432	.3503	.3574	.3645	.3717	.3790	.3863
5	.2843	.2913	.2983	.3054	.3126	.3198	.3270	.3344
6	.2502	.2572	.2642	.2714	.2786	.2859	.2933	.3007
7	.2261	.2332	.2404	.2476	.2550	.2624	.2698	.2774
8	.2084	.2156	.2228	.2302	.2377	.2452	.2529	.2606
9	.1949	.2022	.2096	.2171	.2247	.2324	.2402	.2481
10	.1843	.1917	.1992	.2069	.2147	.2225	.2305	.2385
11	.1758	.1834	.1911	.1989	.2068	.2148	.2229	.2311
12	.1690	.1767	.1845	.1924	.2005	.2086	.2169	.2253
13	.1634	.1712	.1791	.1872	.1954	.2037	.2121	.2206
14	.1587	.1666	.1747	.1829	.1912	.1997	.2082	.2169
15	.1547	.1628	.1710	.1794	.1878	.1964	.2051	.2139
16	.1514	.1596	.1680	.1764	.1850	.1937	.2025	.2114
17	.1486	.1569	.1654	.1740	.1827	.1915	.2004	.2094
18	.1462	.1546	.1632	.1719	.1807	.1896	.1987	.2078
19	.1441	.1527	.1613	.1701	.1791	.1881	.1972	.2065
20	.1424	.1510	.1598	.1687	.1777	.1868	.1960	.2054
21	.1408	.1495	.1584	.1674	.1765	.1858	.1950	.2044
22	.1395	.1483	.1573	.1664	.1756	.1848	.1942	.2037
23	.1383	.1472	.1563	.1654	.1747	.1841	.1935	.2031
24	.1373	.1463	.1554	.1647	.1740	.1834	.1930	.2026
25	.1364	.1455	.1547	.1640	.1734	.1829	.1925	.2021
26	.1356	.1448	.1541	.1634	.1729	.1825	.1921	.2018
27	.1350	.1442	.1535	.1630	.1725	.1821	.1918	.2015
28	.1344	.1437	.1531	.1626	.1721	.1818	.1915	.2012
29	.1339	.1432	.1526	.1622	.1718	.1815	.1912	.2010
30	.1334	.1428	.1523	.1619	.1715	.1813	.1910	.2008

1/ Each factor is the amount of money (in dollars) that must be repaid annually per dollar borrowed to repay a loan at the respective interest rate and in the number of years.

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